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# Mosquito Lagoon Environmental Resources Inventory

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# MOSQUITO LAGOON ENVIRONMENTAL RESOURCES INVENTORY

## INTRODUCTION

This report summarizes Phase I of a water quality and environmental resource inventory project for Mosquito Lagoon. The work was funded by the National Park Service through an Interagency Agreement with NASA at the John F. Kennedy Space Center. Phase I of the project consisted of a comprehensive literature search and the retrieval of data from various federal, state and local agencies. Literature searches were conducted manually through various bibliographic listings as well as electronically with the DIALOG database, the NASA-RECON database and the NASA-ARIN database. Updating of the literature database represents an ongoing process and to date 157 papers, reports and articles have been inventoried. Each article has been numbered and entered into REF-MENU bibliographic software, where it can be accessed by author, title, year or keywords. A listing of the bibliographic index printed by reference number (Ref) is presented in Appendix A. The biotic and abiotic information collected in the Mosquito Lagoon area is listed in Appendix B. A listing of individuals contacted in the process of performing Phase I is found in Appendix C. Appendix D lists the types, age and locations of aerial photographs and satellite images available for Mosquito Lagoon.

In reviewing data and reports relative to environmental resources in Mosquito Lagoon a holistic ecological approach was taken. Studies have been conducted on various components of this lagoon, many as inventories for the Kennedy Space Center's Environmental Impact Statement and documentation requirements. Also, several animal species found in the lagoon are of significant status in terms of mandated protection by U.S. laws. There have been few areas of consistent data collection within Mosquito Lagoon or any region of the Indian River Lagoon (IRL), for that matter, over long periods of time. We do know from the various studies that the system is dynamic and there is much that is not understood.

In the following text, we briefly highlight some of the data and information on climate, hydrogeology, land use, chemistry, flora and fauna that most directly relate to water quality and the historical and current ecological condition of Mosquito Lagoon. At the end of each section a list of reference numbers from the Phase I literature search is provided suggesting additional reading material pertinent to that section.

## OVERVIEW

Mosquito Lagoon is a bar-built type estuary occupying 152.8 km<sup>2</sup> of east central Florida and is considered a sub-basin of the larger Indian River Lagoon System (Clapp 1987). The Indian River Lagoon extends along the east coast of Florida from

Ponce de Leon Inlet near New Smyrna Beach to St. Lucie Inlet near Stuart, a distance of about 220 km. The lagoon system is composed of three interconnected water bodies, Mosquito Lagoon to the north, Indian River to the west and Banana River to the east of Merritt Island (Figure 1). The lagoons vary in width from about 1-2 km in the northern and southern regions to over 8 km near Merritt Island. Average depth is about 1.5 m with depths greater than 3-4 m generally restricted to dredged basins and channels. This region crosses the transition zone between the temperate province to the north and the warm subtropical province to the south. Mosquito Lagoon is located in the northern part of this transition zone and the presence and abundance of species of flora and fauna generally reflect this condition.

Mosquito Lagoon is dominated by shallow flats (less than 1.5 m) that support dense growths of submerged aquatic vegetation (SAV) including manatee grass, (*Syringodium filiforme*), shoal grass (*Halodule wrightii*), widgeon grass (*Ruppia maritima*) and various macroalgae such as *Gracilaria*, *Caulerpa*, *Sargassum*, and *Acanthophora*. Shorelines of the system are dominated by mangroves such as *Laguncularia racemosa* and *Avicennia germinans*. However, this region represents the northern limit of their range and the winter freezes of 1983, 1984, and 1989 significantly impacted their populations (Provancha et al. 1986, personal observation). Fauna in the lagoon system is also dominated by species common to the Carolinian Province such as mullet (*Mugil cephalus*), spotted sea trout (*Cynoscion nebulosus*), red fish (*Sciaenops ocellatus*), sea catfish (*Arius felis*), and blue crabs (*Callinectes sapidus*) to name a few. Subtropical species are present but are less prevalent than in the southern portion of the Indian River Lagoon System. This unique environmental setting makes Mosquito Lagoon part of one of the most diverse estuarine areas in the United States.

## CLIMATE

Climate is a dominating factor controlling water quality and the distribution and abundance of biota. Mailander (1990) presents a comprehensive review of existing climate data for the region, including Mosquito Lagoon. Mosquito Lagoon is situated between 28°38" and 28°58" north latitudes on the east central coast of Florida and has a warm temperate to subtropical climate. Summers are warm and humid and winters are typically mild. Figure 2 shows the mean monthly minimum and maximum air temperatures between 1957 and 1985 measured at Cape Canaveral Air Force Station at the south end of Mosquito Lagoon. The occurrence of freezing temperatures limits the distribution and abundance of plants and animals in this transition region. This topic is discussed in more detail in following sections. The proximity of the lagoon to the Atlantic Ocean moderates extremes in temperature fluctuations to some degree. Comparison of 40 years of daily temperature data from Merritt Island and Titusville showed 30 freezing days at Merritt Island compared to 121 days at Titusville, a few miles inland.

Mean annual rainfall for Merritt Island based on a 76 year dataset is 51.6 inches (131 cm) with a range of 30.5 inches (77.5 cm) to 85.7 inches (217.7 cm). The range for average annual rainfall between 1951 and 1980 for the Mosquito Lagoon area was 48-56 inches (122-142 cm) (Rao 1987). The regional pattern of precipitation, presented in Figure 3, indicates that Mosquito Lagoon averages slightly less rainfall than the Banana River

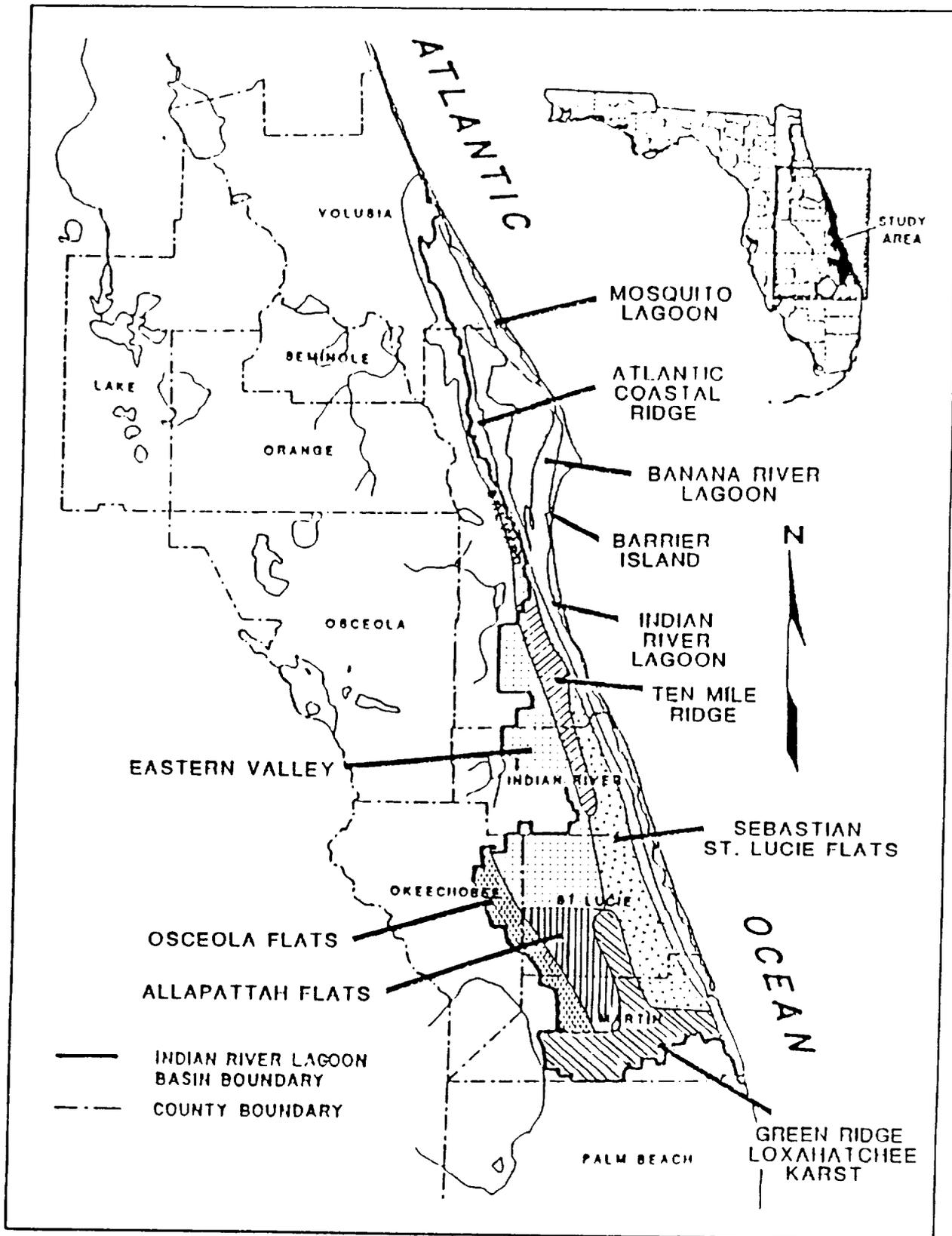


Figure 1. Relative Location of Mosquito Lagoon on the East Central Coast of Florida and its Proximity to the Indian River and Banana River (as modified by Clapp 1987).

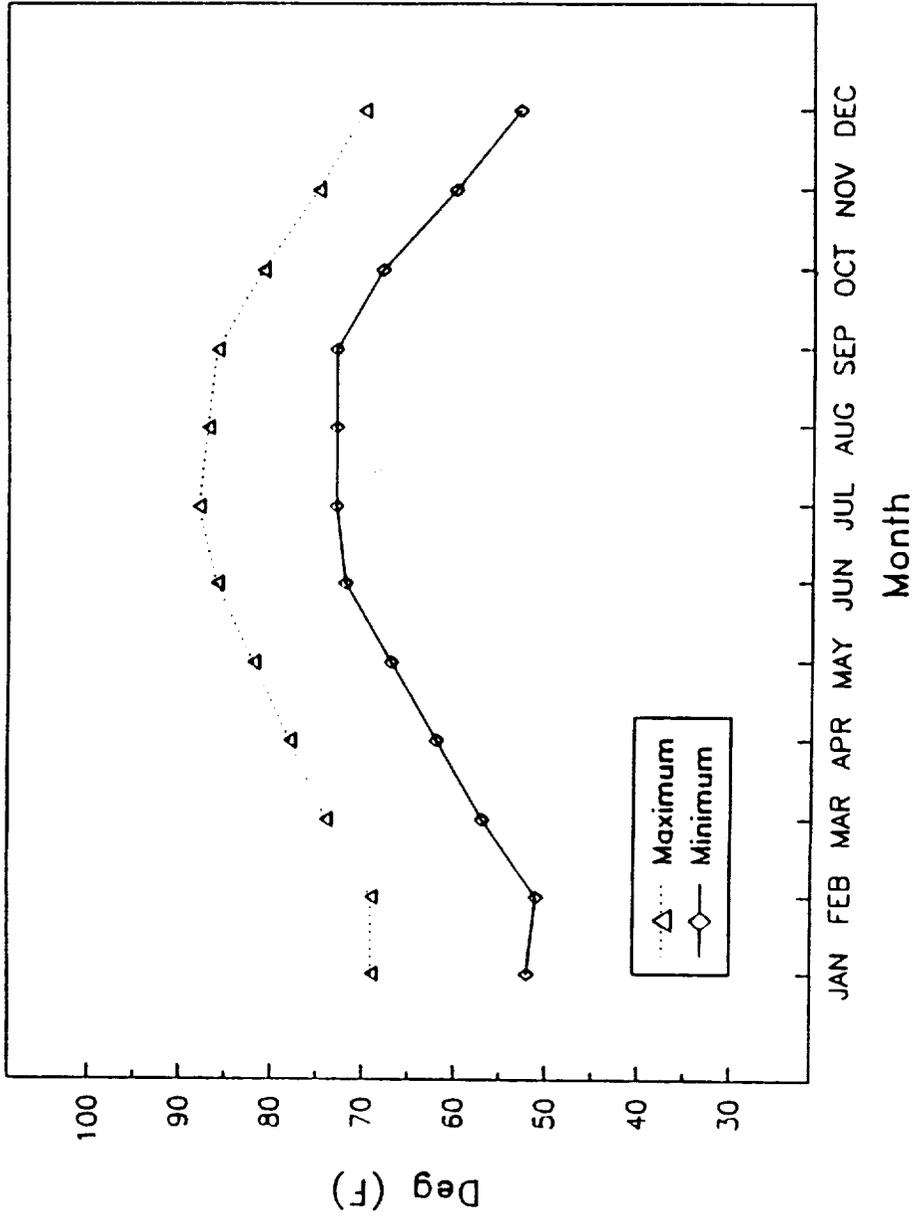


Figure 2. Mean Minimum and Maximum Monthly Air Temperatures for the 28 Year Period between 1957 and 1985 at Cape Canaveral, Florida (Mailander 1990).

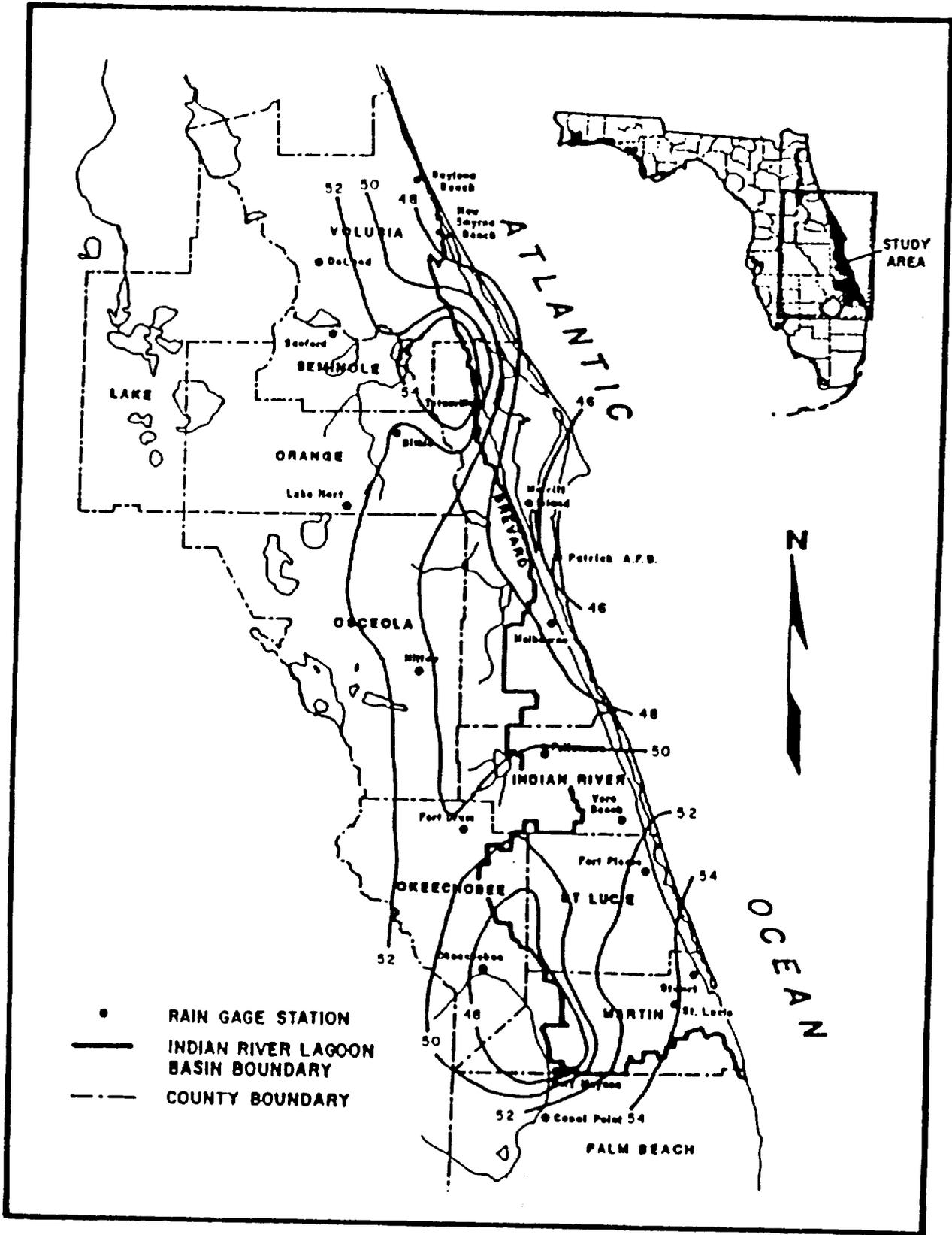


Figure 3. Regional Pattern of Annual Rainfall for Mosquito Lagoon and the East Central Coast of Florida (Rao 1987).

and Indian River areas. The distribution of rainfall is somewhat bimodal with approximately 65% falling between May and October as a result of convectional cells and tropical storms. Winter spring rainfall generally results from passage of frontal systems. On average there are 148 days per year with measurable rainfall. Figure 4 presents the drought and moisture surplus for the region. Two periods of moisture deficit occur: a two month period between March and May and a one month period between November and December. Moisture surplus occurs between June and October. Evapotranspiration data for Cocoa Beach and Cape Canaveral were similar measuring 37.0 inches (94.0 cm) per year. Mean solar insolation values for Cape Canaveral are presented in Figure 5. The summer solstice occurs in June but the month with highest insolation is May because of reduced cloud cover resulting from fewer days of convective thunderstorms. December is the month with lowest insolation. The solar elevation ranges from a maximum of 85.5 degrees above the horizon on June 21 to a minimum of 38.5 degrees on December 21, the longest (14 hr) and shortest (10 hr) days of the year respectively. A summary of average wind and humidity values for Cape Canaveral are shown in Table 1. During the summer wet season east winds predominate. Winter season winds predominate from the north-northwest. Relative humidities are consistently above 75%.

Associated Database Reference numbers: 41, 87, 91.

## LAND USE

The Mosquito Lagoon sub-basin, Figure 6, covers a total area of 288.5 km<sup>2</sup> of which 53% is open water, 15.8% is barrier island and 31.2% is uplands (Clapp 1987). The importance of Mosquito Lagoon to the ecology and economics of the region becomes apparent based on the numerous classifications bestowed on it by regulating agencies. The Environmental Protection Agency (EPA), through the National Estuaries Program, lists the area as an Estuary of National Significance, the state of Florida recognizes Mosquito Lagoon as Outstanding Florida Waters, an Aquatic Preserve, and gives it a water use classification designation of Class II Shellfish Propagation and Harvesting (Gardner 1990). Approximately 65% of Mosquito Lagoon falls within the boundary of the Kennedy Space Center and is managed as part of the Merritt Island National Wildlife Refuge (Clark 1986). An additional 17% is managed by the National Park Service at Canaveral National Seashore (CNS) north of the KSC boundary. This places about 82% of the Lagoon under direct federal jurisdiction.

Activities that may impact water quality in Mosquito Lagoon are regulated by various federal and state agencies. The EPA regulates the discharge of pollutants under the Federal Clean Water Act of 1977 (CWA), as amended by the Water Quality Act of 1987. EPA has adopted numerous regulations to implement the CWA including the development of the National Pollution Discharge Elimination System (NPDES) for both point and non-point source discharges. The U.S. Corp of Engineers administers permitting of Dredge and Fill activities in navigable waters through the authority of the Rivers and Harbours Act of 1899 and in waters of the United States (including isolated wetlands) through Section 404 of the CWA. Chapter 373 of the Florida Statutes authorizes the Florida Department of Environmental Regulation (FDER) to administer regulation of use, management and storage of surface waters. A listing of water quality

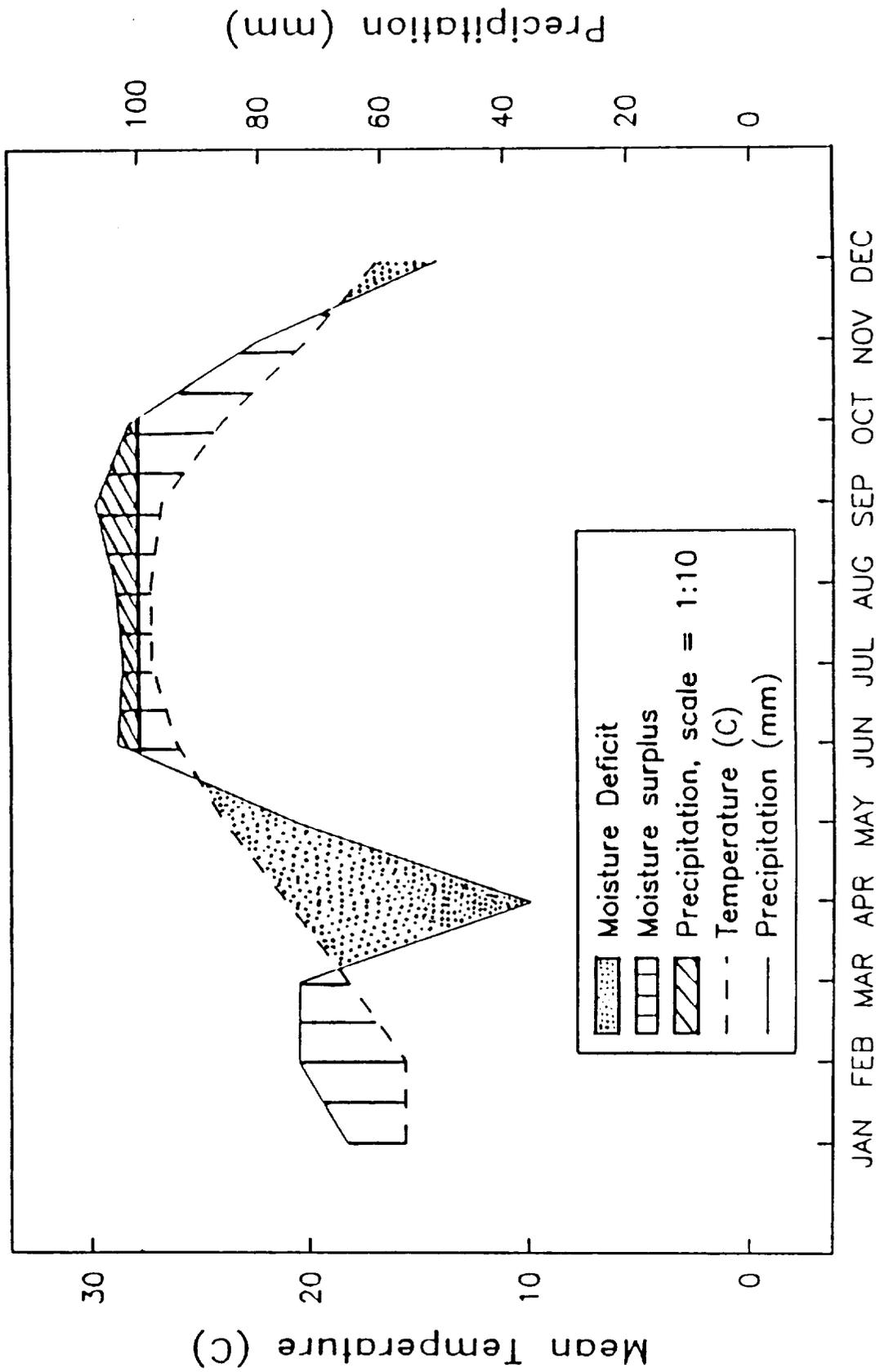


Figure 4. Climate Diagram for the Mosquito Lagoon Region Based on Data Collected at Cape Canaveral, Florida (Mailander 1990).

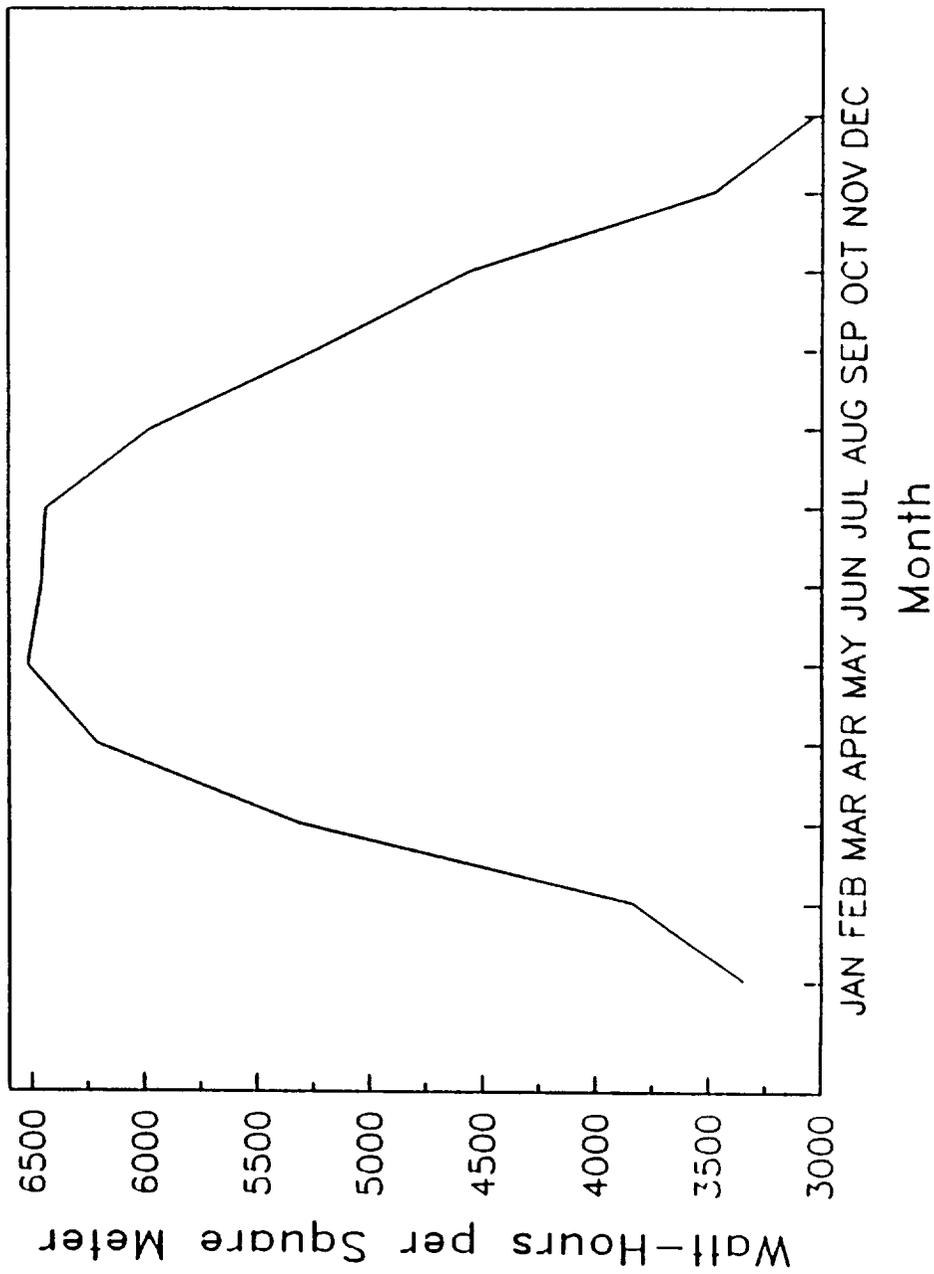


Figure 5. Mean Monthly Solar Insolation for the Cape Canaveral Region (Mailander 1990).

Table 1. Summary of Monthly Wind and Humidity Information for the Cape Canaveral Air Force Station Collected during various periods between 1950 and 1985 (Mailander 1990).

	<u>WIND</u>			<u>HUMIDITY</u>	
	Prevailing (Dir. + Kts.)	Peak Gust (Kts.)	Direction of Peak Gust	Mean Percent Relative Humidity	Relative Humidity
JANUARY	NW8	46	270		80
FEBRUARY	N8	60	240		79
MARCH	N9	48	180		77
APRIL	E8a	53	200		75
MAY	E8	46	270		77
JUNE	E7	50	160		81
JULY	S6	50	220		83
AUGUST	E6	60	090		84
SEPTEMBER	E7	68	160		82
OCTOBER	E8	40	030		78
NOVEMBER	NW8	46	190		78
DECEMBER	NW7	40	310		79

SOURCE: Eastern Space and Missile Command (USAF) (1989)  
a: Eastern Space and Missile Command (USAF) (1982)

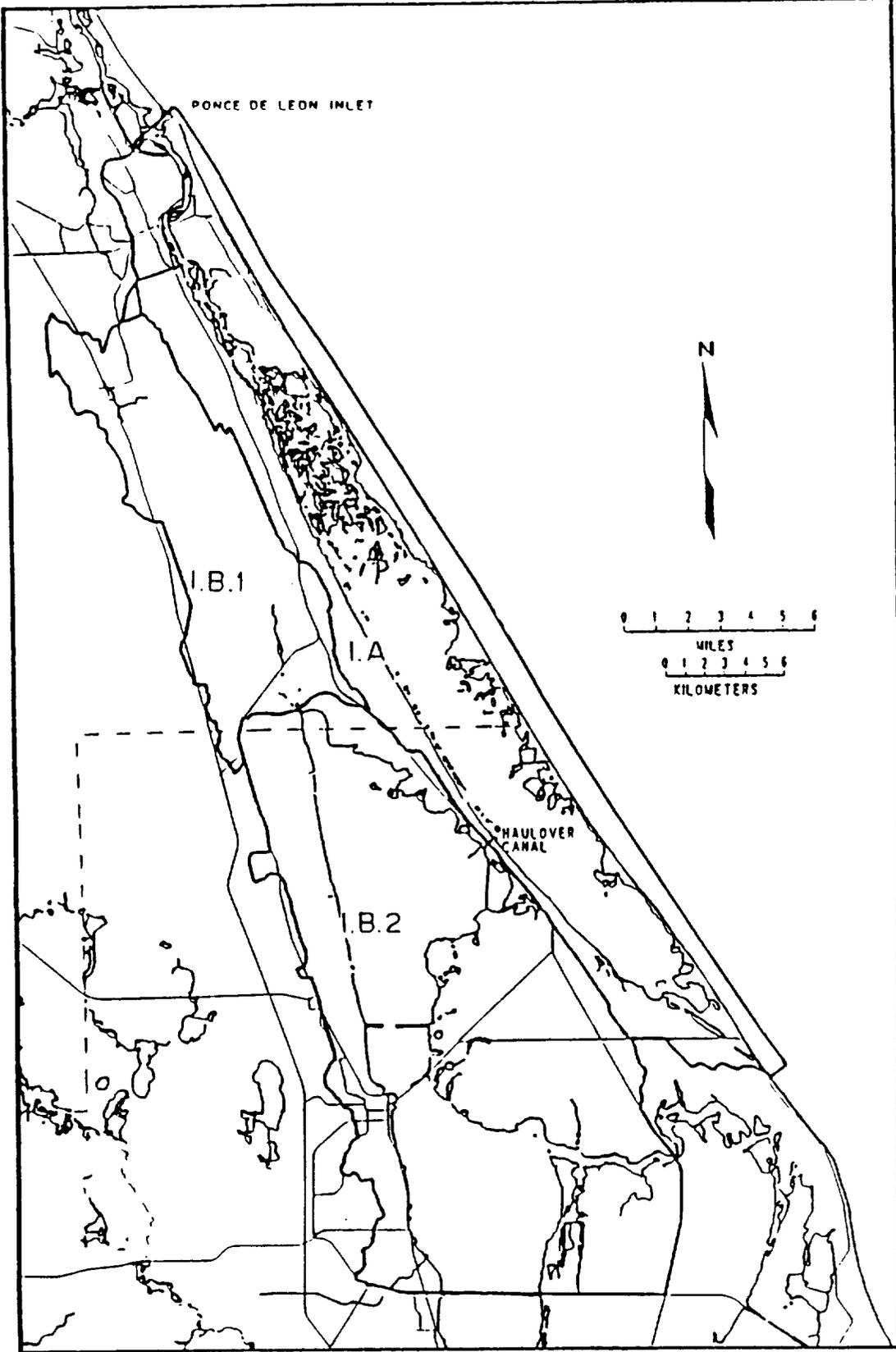


Figure 6. Mosquito Lagoon Sub-Basin Designation within the Northern Part of the Indian River Lagoon System (Clapp 1987).

classifications and standards developed by the FDER is presented in Appendix E. Authority has been delegated to the St. Johns River Water Management District to administer permits and enforcement programs under the Florida Water Resources Act. The Water Management District is also responsible for regulation of stormwater discharges and wetland permitting activities under Chapter 403 of the Florida Statutes.

Land use in the Mosquito Lagoon watershed, outside of the federal properties, falls under the jurisdiction of Volusia County. Three communities, New Smyrna, Edgewater, and Oak Hill are located along the shore of the lagoon. Erwin (1988) reports that there are about 1400 ha of urban land including 1050 ha of residential use associated with this part of the watershed. Low density residential housing makes up 59% and mobile homes make up 39%. On the Barrier Island there are about 425 ha designated as urban. Of these, about 375 ha are residential with 81% being classified as low density housing and 1% being designated for mobile homes.

Associated Database Reference numbers: 10, 38, 40, 92, 109, 110, 122.

## VEGETATION

### 1) TERRESTRIAL

The natural edges of the Mosquito Lagoon shoreline are generally bordered by mangrove (white, black and occasionally red mangrove), sea oxeye, and wax myrtle. There are a few maritime hammocks in the region as well. A variety of vegetation types occur inside the impounded marshes that border the lagoon (i.e., Spartina/Juncus, Batis/Salicornia). Kirkman (1979) provided a vegetation map and species list for a small section (5.25 miles or 8.4 km) of the CNS barrier beach and a few nearby islands in the lagoon. She listed three major vegetation zones and then gave a description of plant communities found within each. The first zone, interior marshlands, were composed of glasswort/saltwort marsh, rush marsh and a mixture of the two. The second zone, swamp, was divided into two types; black mangrove swamp and mixed swamp/marsh. The beach and dune zone involved 9 communities: sea oats/ cordgrass/ salt grass; sea oats/cordgrass/spanish bayonet/palm; saw palmetto/ sea grape; saw palmetto/ thicket shrubs; juniper/shrub thicket; palm/shrub thicket; juniper/shrub palm hammock; hardwood hammock; and finally groundsel/wax myrtle/ sea oxeye/daisy community.

The most recent resource maps that included vegetation and land use bordering the Mosquito Lagoon were produced in 1986 by The Bionetics Corporation using remote sensing techniques, groundtruthing and a geographical information system (GIS). The National Park Service (NPS) maintains a copy of the computerized data.

Schmalzer and Hinkle (1990a) provided a review of the flora of KSC including descriptions and locations of the threatened and endangered plants. Table 2 is a list of the plants of federal concern found within the vicinity of Mosquito Lagoon by Schmalzer and Hinkle.

Table 2. Endangered and Potentially Endangered Terrestrial Species Occurring in the Vicinity of Mosquito Lagoon, from Schmalzer and Hinkle (1990a).

<u>Species</u>	<u>Common Name</u>	<u>Status</u>
<u>Rhynchosia cinerea</u>	Brown haired snoutbean	UR2
<u>Zamia umbrosa</u>	East coast coontie	*
<u>Ophioglossum palmatum</u>	Hand palm	UR5
<u>Lechea cernua</u>	Nodding pinweed	UR2
<u>Hymenocallis latifolia</u>	Spider lily	UR5
<u>Verbena maritima</u>	Coastal vervain	UR2
<u>Cereus eriophorus var fragrans</u>	Fragrant wool-bearing cactus	E

E - endangered.

UR2 - under review for listing, but substantial evidence of biological vulnerability and/or threat is lacking.

UR5 - still formally under review, but no longer considered for listing due to recent information indicating the species is more abundant than previously believed.

\* - Zamia umbrosa is no longer listed but was categorized as UR5 in the past.

Note:

Cereus eriophorus var fragrans was reportedly found in the Turtle Mound section of the park but current thought is that the species is actually Cereus gracilis which is not federally listed but under review.

## 2) AQUATIC VEGETATION

The Indian River Lagoon is considered to be a seagrass-based ecosystem (Clark 1975, Schooley 1977). The pulses in seagrass detrital cycles strongly effect the benthic invertebrate populations which then effect the benthic feeding fishes (Schooley 1977). However, the general concensus is that due to nutrient enrichment of the Indian River Lagoon, primary productivity is changing from submerged aquatic macrophytes to phytoplankton (Windsor and Steward 1987).

Seagrass beds within the bounds of the Kennedy Space Center which included Mosquito Lagoon (Figure 7), were mapped beginning in 1983 (Provancha and Willard 1984). The northern end of Canaveral National Seashore was mapped in 1986 specifically for the National Park Service. This information is currently stored on the GIS at the KSC Remote Sensing and GIS Laboratory. Total areal coverage of submerged aquatic vegetation (SAV) in Mosquito Lagoon to the northern Park Service boundary was 15,403 acres (6233.59 ha). Maps included the delineation of four density classes, representing percent cover of the vegetation and were 10-40%, 40-70%, 70-100% and undiscernable. Sixty-one percent of the SAV were classified as very dense (70-100% coverage class).

In addition to seagrass mapping in the lagoon, six nearshore seagrass transects, Figure 8, have been monitored from 1983 to the present in the southern end of the lagoon between Gallinipper Point and Max Hoeck Back Creek. Three species of seagrass have been observed on these transects, Halodule wrightii, Ruppia maritima, and Syringodium filiforme. Halodule has continued to be the dominant species along the transects (see Figure 9). Transects were located in water depths ranging from .02 m to 0.7 m and averaged about 0.3 m.

Mendonca (1983), studying the feeding ecology of immature green turtles, sampled seagrasses along three transects in Mosquito Lagoon in 1977-1978. Transects were used to determine the species composition, the relative percentages and depth of occurrence of seagrasses and macrophytic algae. Syringodium filiforme and Halodule wrightii were found to be the dominant rooted macrophytes, constituting an annual average of 76% and 9.9%, respectively, of the total sampled plant composition. Rooted macrophytes showed a sharp zonation as seen in other regions of the Indian River Lagoon, with Halodule dominating at depths of up to 0.4-0.8 m but then being displaced by Syringodium up to depths of 1.2 m.

Associated Database Reference numbers:  
5, 15, 36, 42, 54, 57, 62, 63, 72, 77, 88, 74, 86, 99, 112, 119.

## GEOHYDROLOGY

The barrier island complex of the Mosquito Lagoon sub-basin displays a history of deposition and erosion through geologic time related to the periodic rise and fall of sea level. Schmalzer and Hinkle (1990b), Toth (1987), Clark (1986), and Gardner (1990) provide reviews of the existing geohydrologic literature for the region. A

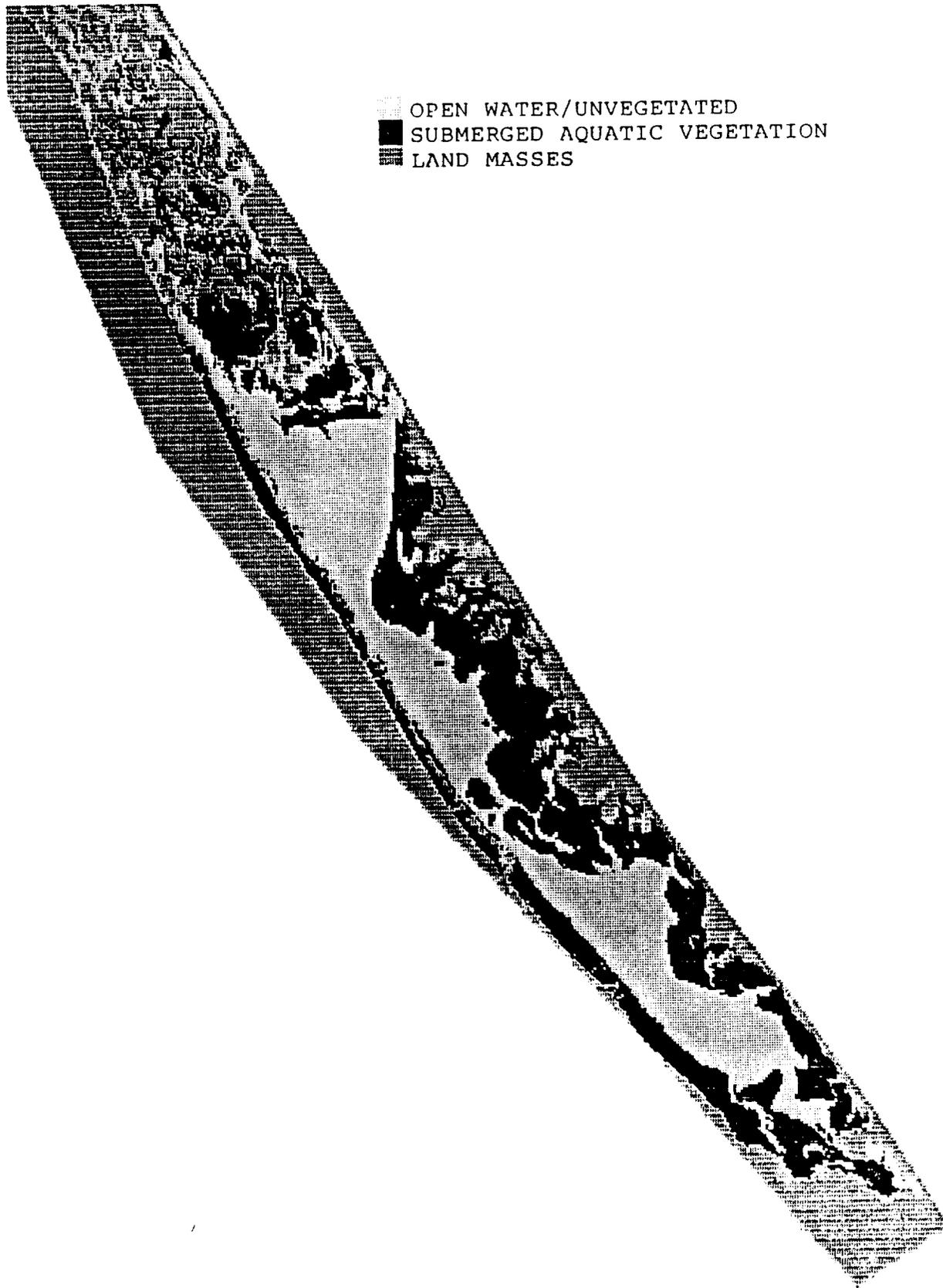


Figure 7. The Distribution of Submerged Aquatic Vegetation in Mosquito Lagoon, Based on Groundtruthing and Interpretation of 1983 and 1986 Imagery.

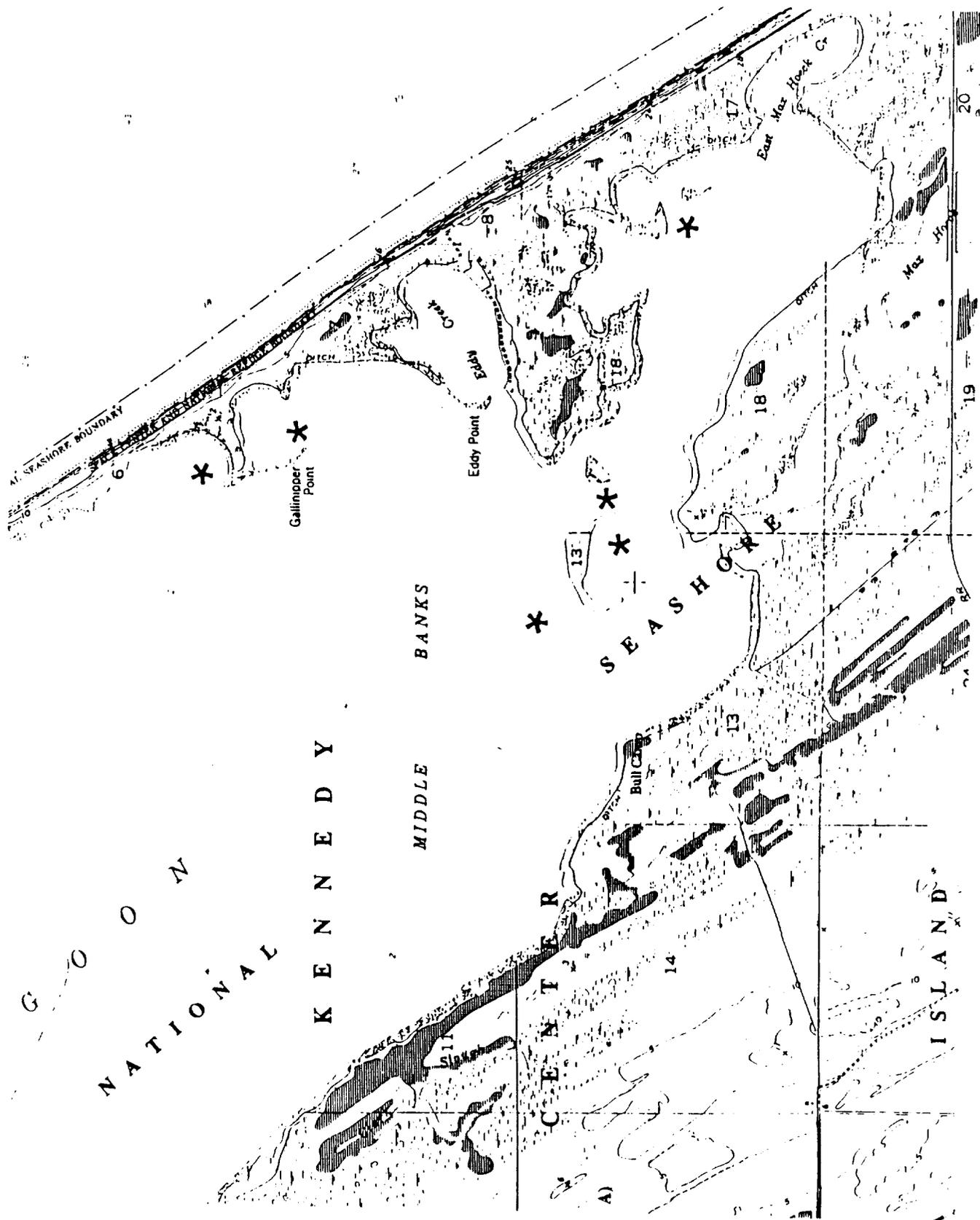
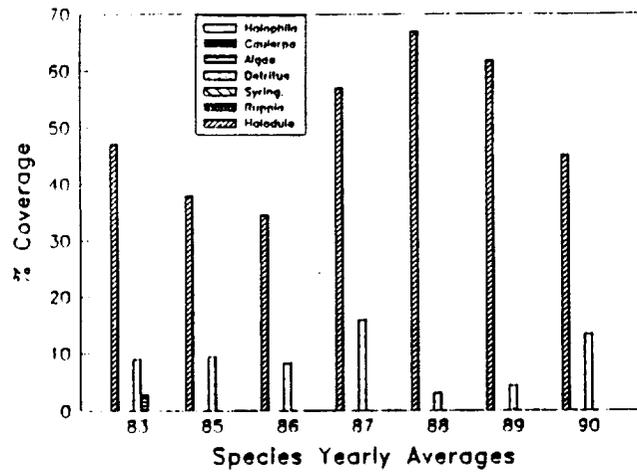
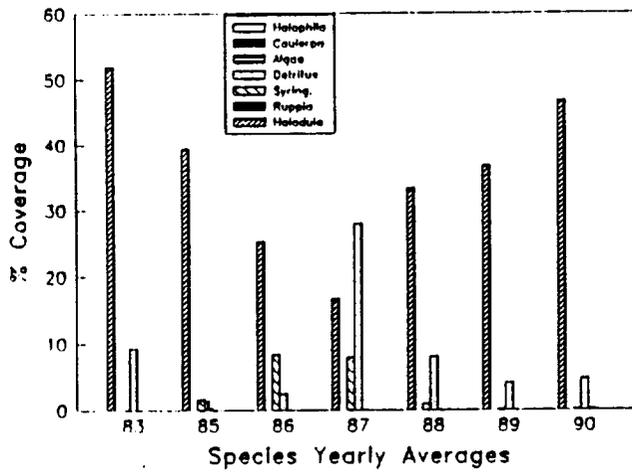


Figure 8. Locations of the Six Seagrass Transects Monitored Annually in Mosquito Lagoon by the Bionetics Corporation for NASA's Ecological Program.

### Seagrass Coverage SGSMLS20



### Seagrass Coverage SGSMLS21



### Seagrass Coverage SGSMLS22

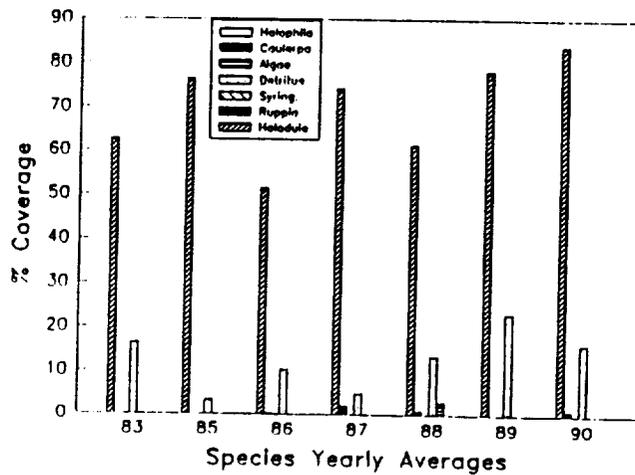


Figure 9. Temporal Variation in the Percent Coverage of Seagrass Along Three Transects Located in Southern Mosquito Lagoon.

summary of the geohydrologic setting is presented in Table 3 and Figure 10. There are three basic units of geohydrologic interest: the surficial aquifer, the regional confining unit, and the Floridan aquifer (McGurk et al. 1989). During the Eocene, the Avon Park limestone and the Ocala Group were deposited and are considered the oldest formations beneath Mosquito Lagoon. These formations contain the Floridan aquifer with a hydraulic transmissivity that ranges between 90,000 and 300,000 gallons per day per square foot (3,785,400 and 12,618,000 liters per day per square meter).

Water quality in the Floridan aquifer is variable depending on location. Beneath the Mosquito Lagoon sub-basin the water is reported to be brackish (Clark 1987) with chloride concentrations ranging between 250 and 1000 mg/l (Toth 1987). These chloride concentrations are either a function of the saltwater/freshwater interface or they represent relic seawater that was entrapped in the aquifer during the Pleistocene. The principal fresh water recharge area for the Floridan aquifer in this region is associated with the karstic Crescent City and Deland ridges to the north and west of the lagoon (McGurk et al. 1989) in an area where the water table is higher than the potentiometric surface. Recharge also occurs to a lesser degree as leakage through the interbedded surficial sediments in the Eastern Valley, Atlantic Coastal Ridge, or Atlantic Beach Ridge. Toth (1987) defines the Mosquito Lagoon sub-basin as an area of active discharge from the Floridan Aquifer. Discharge may occur through springs, artesian wells, or leakage into overlying aquifers through confining beds.

The Hawthorn Formation was deposited during the Miocene and because of its low permeability it may act as a confining layer that retards upward movement from the artesian Floridan aquifer and downward movement or recharge from the overlying surficial aquifer. Beneath Mosquito Lagoon the Hawthorn sediments are estimated to be approximately 50 to 100 ft thick (15.2 to 30.5 m) (McGurk et al. 1989) and approximately 75 feet (22.9 m) below the surface at Ponce de Leon Inlet (Toth 1987). The hydraulic conductivity ranges between 0.001 and 0.03 ft (.0003 to .009 m) per day. Above the Hawthorn formation rests approximately 50 to 100 ft (15.2 to 30.5 m) of interbedded sand, shell and clay sediments including Pleistocene to Recent sand, Clayey sand, or Anastasia Formation coquina. Late Miocene and Pliocene sand, shell and clay layers are also incorporated into the area which is classified as the surficial aquifer (McGurk et al. 1989). Clark (1987) reports that fresh water is found only in the surficial aquifer. Hydraulic conductivities average 11 ft (3.4 m) per day (73 gallons per day per square foot) and precipitation is the primary source of recharge. Only about 0.5 % of the annual average rainfall reaches the groundwater reservoir. Approximately 87% of annual precipitation is lost through evapotranspiration, 11% is lost through seepage and canals and 1.5% is represented by overland runoff. Erwin (1988) reports different values with 67% being lost to evapotranspiration, 19% to runoff and 14% to groundwater storage.

Surficial groundwater inputs to lagoon type estuaries may be substantial depending on geomorphology and in the case of lagoonal systems with small watersheds, often represent the single largest input of water to the system (Lee and Olsen 1985) outside of direct precipitation. Figure 11 depicts the ground water flow pattern in the surficial aquifer on north Merritt Island. This ground water can be of highly variable quality, depending on soils, and the type of development and industrialization that has

Table 3. Summary of Geohydrologic Setting for Mosquito Lagoon and the Surrounding Areas (taken from Schmalzer and Hinkle 1990b after Clark 1987).

Aquifer	Geologic Strata	Recharge Areas	Discharge Area	Water Quality
Principal Artesian Aquifer:				
Floridan Aquifer	Eocene limestones - Ocala Group, Avon Park Formation	Central Florida - West Osceola, South Orange, and Polk Counties; Mims - Titusville ridge	Atlantic Ocean via offshore submarine springs, upward leakage where Hawthorn Formation thins	Highly mineralized, primarily chlorides
Secondary Artesian Aquifers:				
Hawthorne Limestone Aquifer	Thin beds of weathered limestone, sandstone, and sand within the Hawthorn Formation	Leakage upward from Floridan aquifer	Unknown	Moderately brackish
Shallow Rock Aquifer	Tamiami Formation - shelly, partially consolidated quartz sand and some limestone	Leakage upward from Floridan aquifer	Unknown	Brackish
Semi-artesian Shell and Sand Beds	Discontinuous sand and shell beds within Caloosahatchee Marl Equivalent	Little freshwater recharge, may act as conduits for seawater intrusion	Unknown	Moderately brackish, generally poorer than Floridan aquifer
Unconfined Water Table Aquifer:				
Surficial Aquifer	Pleistocene and Recent desposits - sand, shell, coquina, silt, and marl	Rainfall and direct infiltration, particularly that on central sand ridges of island	Drainage canals and ditches (11%), evapotranspiration including loss from swales (87%), seepage to impoundments, lagoons, and ocean (0.5%)	Fresh in center of island, becomes mineralized toward lagoons and ocean

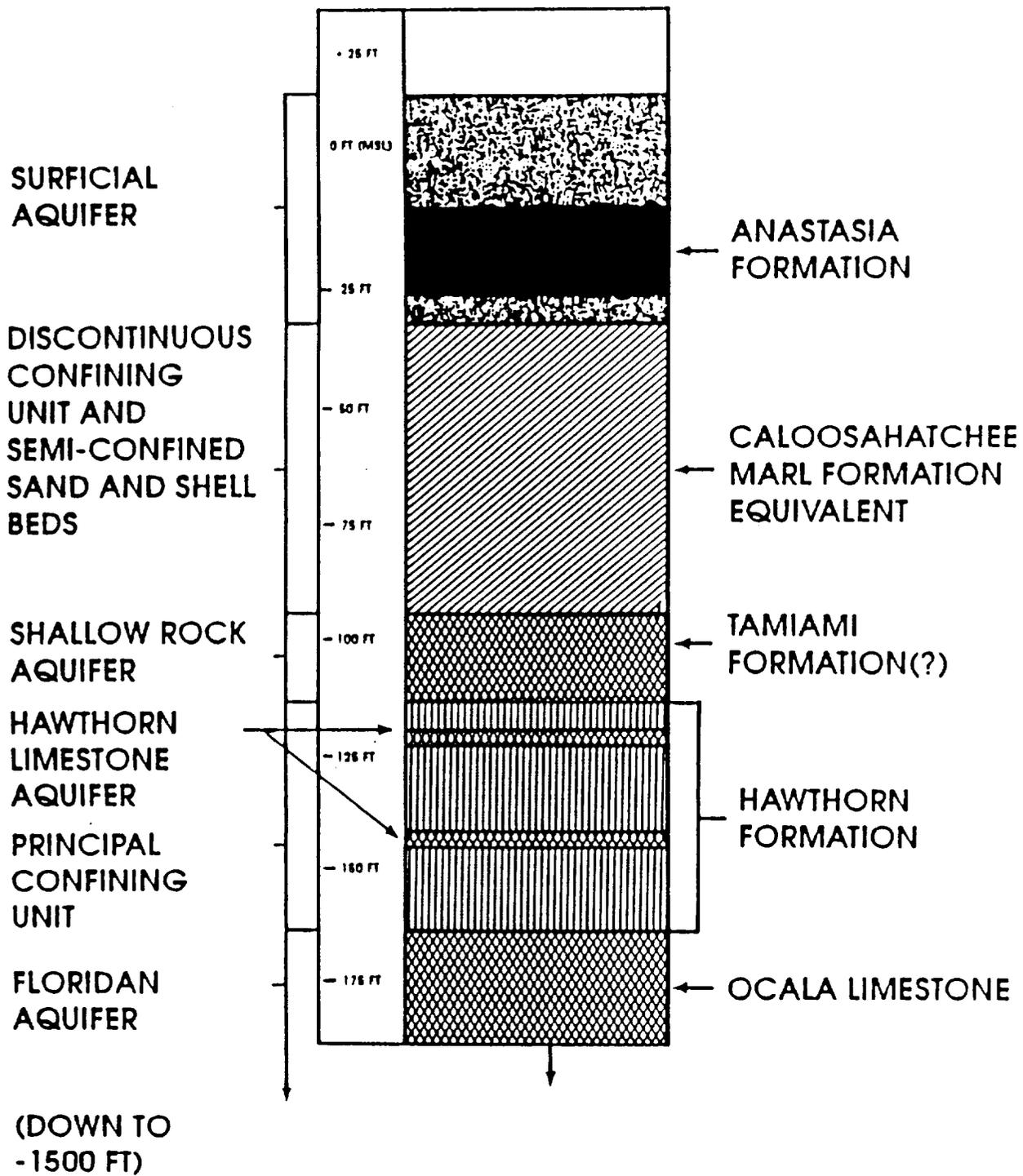


Figure 10. Diagrammatic Representation of Geohydrologic Setting Beneath Mosquito Lagoon (Schmalzer and Hinkle 1990b and Clark 1987).

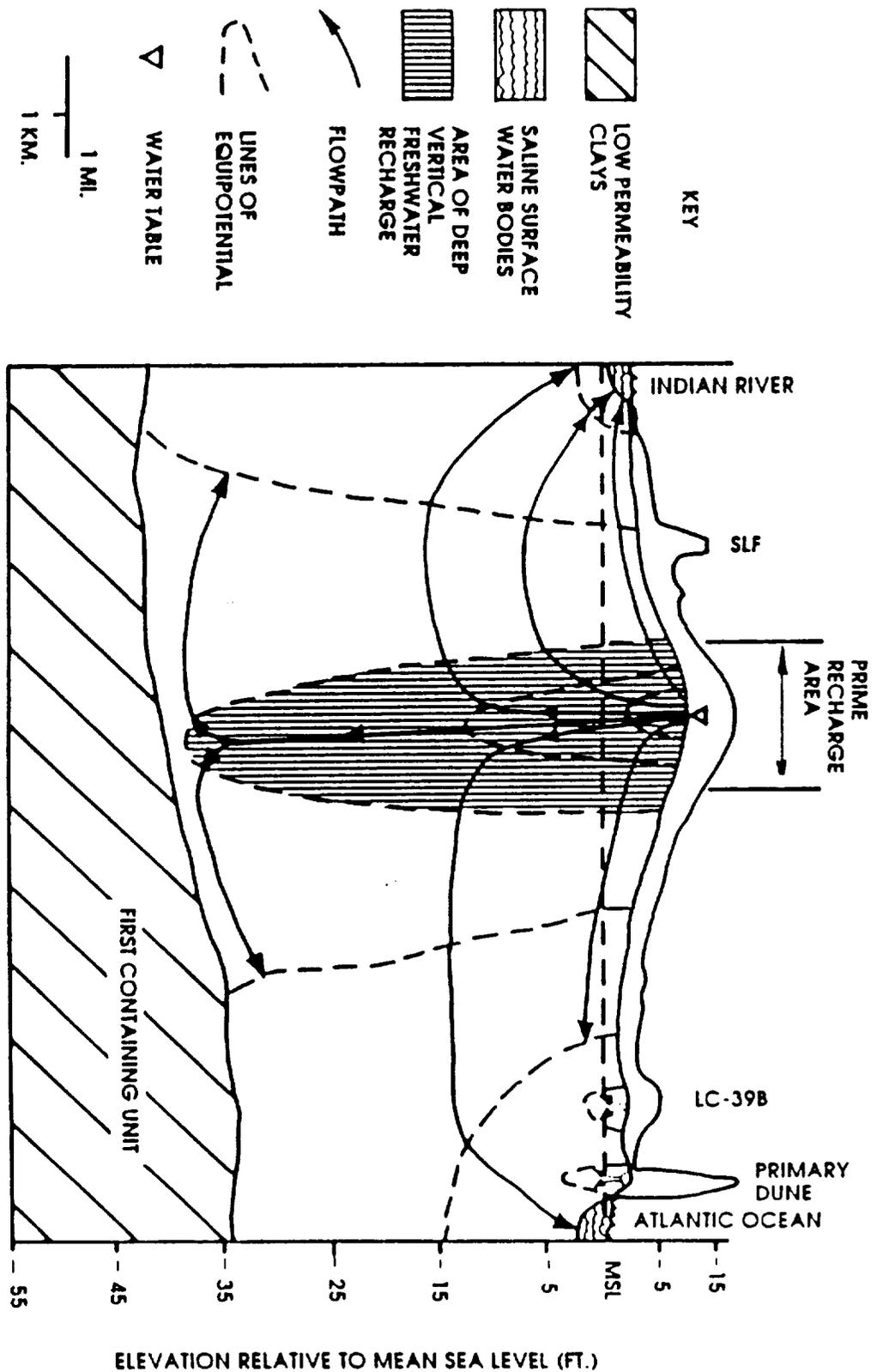


Figure 11. Diagrammatic Representation of Groundwater Recharge and Flow through the Surficial Aquifer on North Merritt Island (taken from Schmalzer and Hinkle 1990b after Clark 1987).

occurred on the watershed. An example of water quality data for the surficial aquifer on north Merritt Island is presented in Table 4 (Clark 1987). No information on nutrient loading to Mosquito Lagoon through surficial groundwater was observed during the literature review. Estimates in Lee and Olsen (1985) suggest that approximately 50-75% of the nitrogen entering the groundwater is derived from septic systems and lawn fertilizers. Zimmermann et al. (1985) reported a dissolved reactive phosphate flux of  $29-50 \times 10^{-6} \text{ g/m}^2$  per day resulting from groundwater flow to the nearshore sediments in the Indian River Lagoon near Ft Pierce.

Figure 12 depicts the surficial groundwater recharge areas for the Kennedy Space Center. The central ridge running north-south through Merritt Island, the barrier island to the east and the Atlantic Ridge to the west of Mosquito Lagoon represent the primary area for recharge of the surficial aquifer. Rainfall on these areas percolates rapidly through the sandy soils producing a head or pressure gradient that results in the downward and lateral movement of relatively high quality waters in the surficial aquifer. Movement in the aquifer is primarily toward the low lying wetlands, mosquito impoundments and estuarine lagoons. Down gradient from the sandy ridge areas the ground water recharge potential decreases as the relationship between the elevation and depth to the aquifer decreases (i.e., the aquifer is on average closer to the surface) reducing the amount of head pressure that can be generated by infiltration. Further down slope in areas adjoining wetlands the recharge potential is further reduced and during periods of high rainfall the surficial aquifer may be higher than the land surface producing ponding. As shown in Figure 12 these three regions are described as the Prime, Good, and Fair-poor recharge areas for the surficial aquifer. This relationship between the surficial aquifer and the overlying undulating ridge system of ancient sand dunes has resulted in the longitudinal pattern of scrub or slash pine flatwoods and wetland swale vegetation on Merritt Island.

The lagoon basin lies between the Atlantic Coastal Ridge which is 25 ft (7.6 m) above mean sea level and the barrier island which ranges in height from sea level to 30 feet (9.1 m) above mean sea level (Gardner 1990). The Atlantic Coastal Ridge is characterized as a sandy ridge dominated by the Daytona-Satellite-Astatula soil series. This series consists of sandy, silicious, hyperthermic and uncoated families of soils with predominantly marine origins. The barrier island is dominated by soils of the Palm Beach-Paola-Canaveral series. These soils are Carbonitic, hyperthermic families of soils dominated by marine sands and shell fragments (Schmalzer and Hinkle 1990b). The Cape Canaveral-Merritt Island barrier island complex that forms the southern border of Mosquito Lagoon is described as unique along the Florida coast; it is not associated with rivers or former deltas as are capes on the coast of the Carolinas. The geologic history of the Cape and Merritt Island is complex and is not a simple progradational feature which developed in recent times. The older portion of Merritt Island consists of beach deposits >240,000 years old. Estimates of the current beach age on Merritt Island suggest formation about 30,000 year ago, while mainland deposits date back approximately 110,000 years.

Development of the barrier island forming the eastern boundary of Mosquito Lagoon and the present Cape Canaveral peninsula began approximately 7,000 years ago. Unlike the Cape, the history of the barrier beach is marked by erosion, overwash and landward migration rather than progradation. Five tidal inlets once connected the

Table 4. Example of Water Quality Data Collected for the Surficial Aquifer on Merritt Island North of Banana Creek (Clark Eng. and Sci. 1987).

SUBAQUIFER:COASTAL BARRIER \ UPPER ZONE

	DRINKING WATER STNDS.	MEAN AMBIENT CONC.	MINIMUM AMBIENT CONC.	MAXIMUM AMBIENT CONC.	NUMBER SAMPLES BDL	TOTAL NUMBER OF SAMPLES
<b>INORGANICS</b>						
Chlorides	(S) 250	1854.00	21.00	10200.00	0	40
Manganese	(S) 0.05	<0.09	<0.02	0.43	11	40
Nitrate	(P) 10.	<0.01	<0.01	0.08	34	40
Sodium	(P) 160	1059.00	9.00	4200.00	0	40
Sulfate	(S) 250	461.00	<10	2300.00	7	40
<b>PHYSICAL PARAMETERS</b>						
TDS	(S) 250	4426	150	19000	0	40
pH	(S) 6.5	7.50	5.70	8.50	0	40
Alkalinity		416	5	940	0	40
<b>TRACE METALS</b>						
Arsenic	(P) 0.05	<0.08	<0.05	0.16	36	40
Barium	(P) 1.	<0.03	<0.10	<1.0	40	40
Cadmium	(P) 0.01	<0.013	<0.005	0.03	36	40
Chromium	(P) 0.05	<0.037	<0.02	<0.05	40	40
Copper	(S) 1.	<0.06	<0.02	0.80	38	40
Iron	(S) 0.30	4.38	<0.03	23.00	38	40
Lead	(P) 0.05	<0.06	<0.05	0.11	30	40
Mercury	(P) 0.002	<0.002	<0.002	<0.002	40	40
Selenium	(P) 0.01	0.08	<0.01	0.33	25	40
Silver	(P) 0.05	<0.03	<0.01	<0.05	40	40
Zinc	(S) 5.	<0.07	<0.02	0.70	16	40
Gross Alpha (pCi/l)	(P) 15	19.60	<0.20	67.50	0	28
Fecal Coliform (n./ll)	(P) 1	<10	<10	<10	28	28

\* ALL CONCENTRATIONS EXPRESSED IN mg/l UNLESS OTHERWISE SPECIFIED.

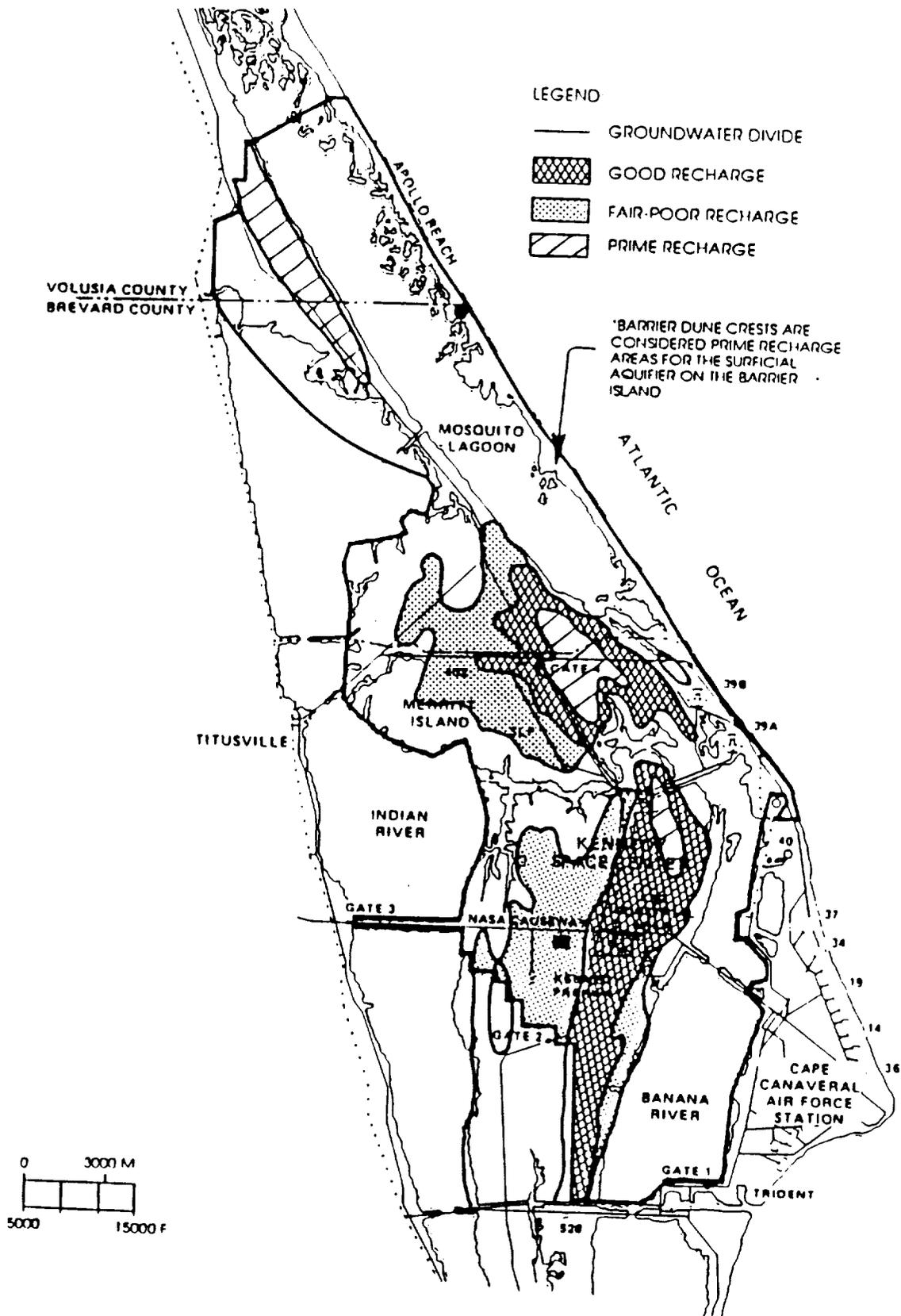


Figure 12. Locations of Surficial Aquifer Recharge Zones on the Kennedy Space Center and Related Areas of Mosquito Lagoon (taken from Schmalzer and Hinkle 1990b after Clark 1987).

Mosquito Lagoon with the Atlantic Ocean (Mehta and Brooks 1973). These previous inlets were located at the mangrove island clusters found between Max Hoeck Creek and Turtle Mound. The inlets appear to be older in age as you progress southward. The last invasion of new quartz sand to the lagoon occurred about 1500 years ago and so the youngest inlet was at Turtle Mound and dates to approximately 500 A.D. The geological strata for these old inlet areas contain oysters indicating that the area was open to tidal flushing. Mosquito Lagoon was not connected to the Indian River until the construction of Haulover canal in 1854 (Snelson 1983).

Associated Database Reference numbers: 52, 87, 141, 142.

## HYDROLOGY AND WATER QUALITY

Water quality measurements at any given moment are a function of numerous interacting influencing variables of which two categories, geophysical and meteorological, are dominating (Lasater 1975). Of major importance in Mosquito Lagoon are distance from inlets, watershed characteristics, groundwater interactions, wind speed and direction, rainfall, temperature, and solar radiation. Superimposed over these are a number of biogeochemical processes that influence water chemistry. These include photosynthesis, respiration, decomposition, nutrient fluxes, and mineral dissolution.

Examination of existing water quality datasets for Mosquito Lagoon revealed several problems that make interpretation and trend analysis difficult. The most significant problem is the lack of a long term consistent dataset (>10 yrs) with which to work. Recent implementation of a long term program under Surface Water Improvement and Management (SWIM) should rectify this problem in the future. Flint (1985) describes the importance of long term chemical and biological data in the development of estuarine models that describe fluctuations in biological communities. His results for Corpus Christi Bay, Texas suggest that in some estuaries episodic events, such as flooding with fresh water, are the primary stimulators of estuarine production over long periods. Nutrient recycling from the benthos is the major source of nutrients supporting primary production. This recycling process is however somewhat inefficient with some materials being lost from the system by burial and biological export (migration and harvest). Episodic events such as hurricanes or major storms replace and redistribute the nutrients lost from the system sustaining long term productivity.

Mendonca (1983) reported the average depth of Mosquito Lagoon to be 1.5 m. Based on these data, the lagoon volume is estimated at approximately  $2.3 \times 10^8 \text{ m}^3$  of water. The primary freshwater source for the system is direct rainfall which averages 48 inches (122 cm) per year. On a yearly basis this represents a direct input volume of approximately  $1.8 \times 10^8 \text{ m}^3$  of water or about 78% of the total lagoon volume. Rainfall on the watershed equals approximately  $1.6 \times 10^8 \text{ m}^3$  per year or 70% of the volume of the lagoon. Based on estimates from Clark (1987) and Erwin (1988) about 15% of the rainfall on uplands runs off to the lagoon representing 18.3 cm and a volume of  $2.4 \times 10^7 \text{ m}^3$  or 10% of the lagoon volume. Evapotranspiration for the region is estimated to be about 94 cm or 77% of total rainfall for the year (Mailander 1990). This produces a

surplus rainfall on the watershed of 28 cm. This remaining rainfall on the watershed has the opportunity to percolate to groundwater storage. Clark (1987) presents hydrographs (Figure 13) that display the rapid response of the water table to precipitation.

Tidal flow of sea water through Ponce de Leon Inlet is believed to have minimal influence on water quality in most of Mosquito Lagoon. At the inlet, mean tidal range is estimated at 2.3 ft (0.7 m) with the degree of tidal flushing diminishing rapidly to the north and south of the inlet. Hand et al. (1986) indicate that tidal influences extend 10 miles (16 km) from the inlet; however, Jones and Mehta (1978) report that the tidal effects are a function of several factors and generally range between 1.6 (2.6 km) and 6 miles (9.7 km). In a study of shellfish beds in the Canaveral National Seashore, tidal fluctuations ranged from a high of 6 inches (15 cm) at the north end of the study site to a low of 2 inches (5 cm) at the south end of the study site (Grizzle 1990).

Erwin (1988) conducted a comprehensive estuarine water quality assessment as part of the Volusia County Coastal Management Element. The Mosquito Lagoon surface drainage basin extends from Ponce de Leon Inlet in the north to the southernmost extent of the lagoon in an area of impounded high marsh designated as Max Hoeck Back Creek. Potential pollution sources in the Mosquito Lagoon basin include point and non-point sources and data are summarized by Erwin (1988). Two point source sewage discharges with a maximum flow of 5.0 MGD (18.9 MLD) are permitted by the FDER in the Mosquito Lagoon Basin. An additional 7.5 sources with a maximum flow of 33.2 MGD (125.6 MLD) are permitted for the area north of Ponce de Leon inlet. Currently discharges from these sewage treatment plants average about 50 to 75 % of permitted levels. Estimates of non-point source discharges to the Mosquito Lagoon basin in the Volusia County area are summarized in Table 5.

The single largest unquantified source of non-point pollution is septic tank systems within the basin. It is estimated that approximately 22,000 septic systems are in use in the Volusia County coastal zone with an additional 3,000 projected through the year 2005. The largest concentrations of septic systems are to the north of Mosquito Lagoon in the more highly developed areas, but a concentration does exist southwest of the New Smyrna Airport (Erwin 1988).

Water quality in Mosquito Lagoon has recently been classified as fair to good based on data available from the EPA STORET database between 1970 and 1987 using a Trophic State Index that includes chlorophyll, secchi depth, nitrogen and phosphorus concentrations (Hand et al. 1988). Annual median values for parameters from the dataset are presented graphically in Figure 14. Water quality monitoring data for Mosquito Lagoon are reported for numerous stations with highly variable lengths of record. Examples from the STORET database are presented in Table 6. Locations of historic water quality sampling stations are shown in Figures 15. In response to the SWIM program staff members of the St. Johns River Water Management District, Volusia County, and Brevard County implemented a lagoon wide water quality monitoring program to rectify the problems observed in the datasets. The new sampling program was initiated in October 1988 and locations of the current stations are shown in Figure 16. Results for 20 stations collected in Volusia County are presented in Table 7.

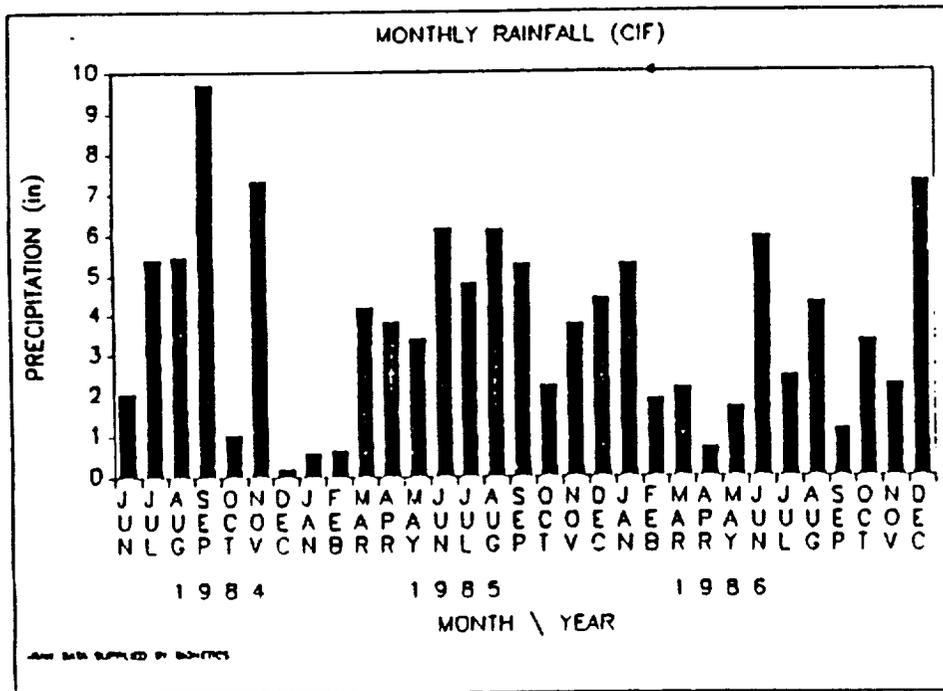
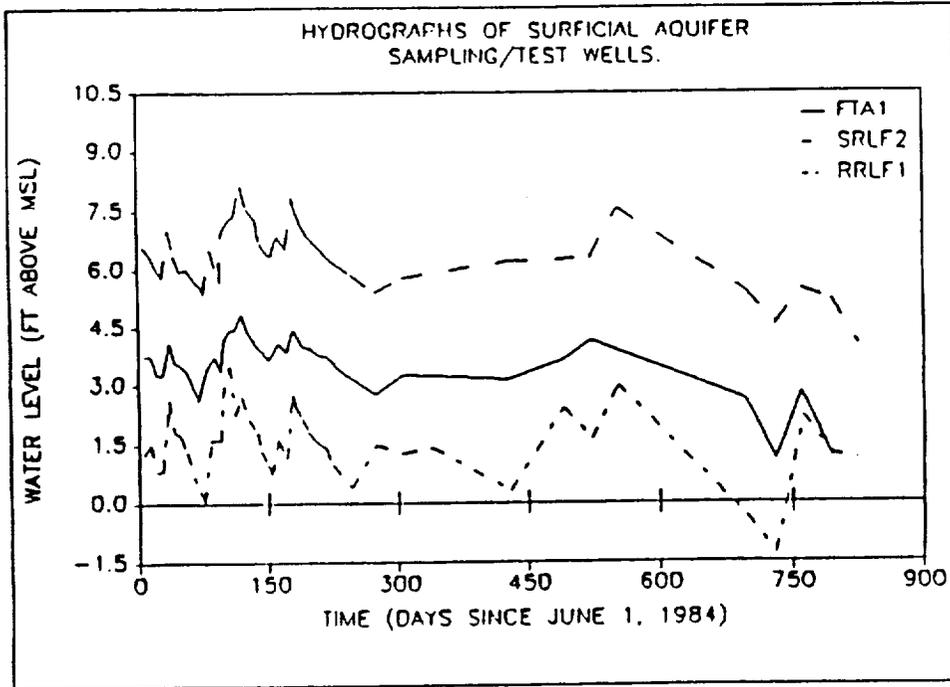


Figure 13. Hydrograph of Surficial Aquifer Levels Showing the Response to Monthly Rainfall Levels (Clark 1987).

Table 5. Projected Loading Rates of Five Water Quality Constituents from Six Different Land Use Categories in the Volusia County Part of the Mosquito Lagoon Sub-Basin (Erwin 1989).

SUB BASIN NAME LANDUSE	ACRES	5-DAY BOD (LBS/DAY)	TOTAL SUSPENDED SOLIDS (LBS/DAY)	TOTAL NITROGEN (LBS/DAY)	TOTAL PHOSPHORUS (LBS/DAY)	OIL & GREASE (LBS/DAY)
Indian River North	51,615	2,608	35,256	1,034	118	641
Urban	9,093	2,167	22,022	797	107	623
Suburban	727	94	347	6	2	18
Agricultural	1,639	58	6,174	63	3	0
Woodland	19,477	267	4,642	144	5	0
Wetland	799	22	2,071	24	1	0
Water	19,880	0	0	0	0	0

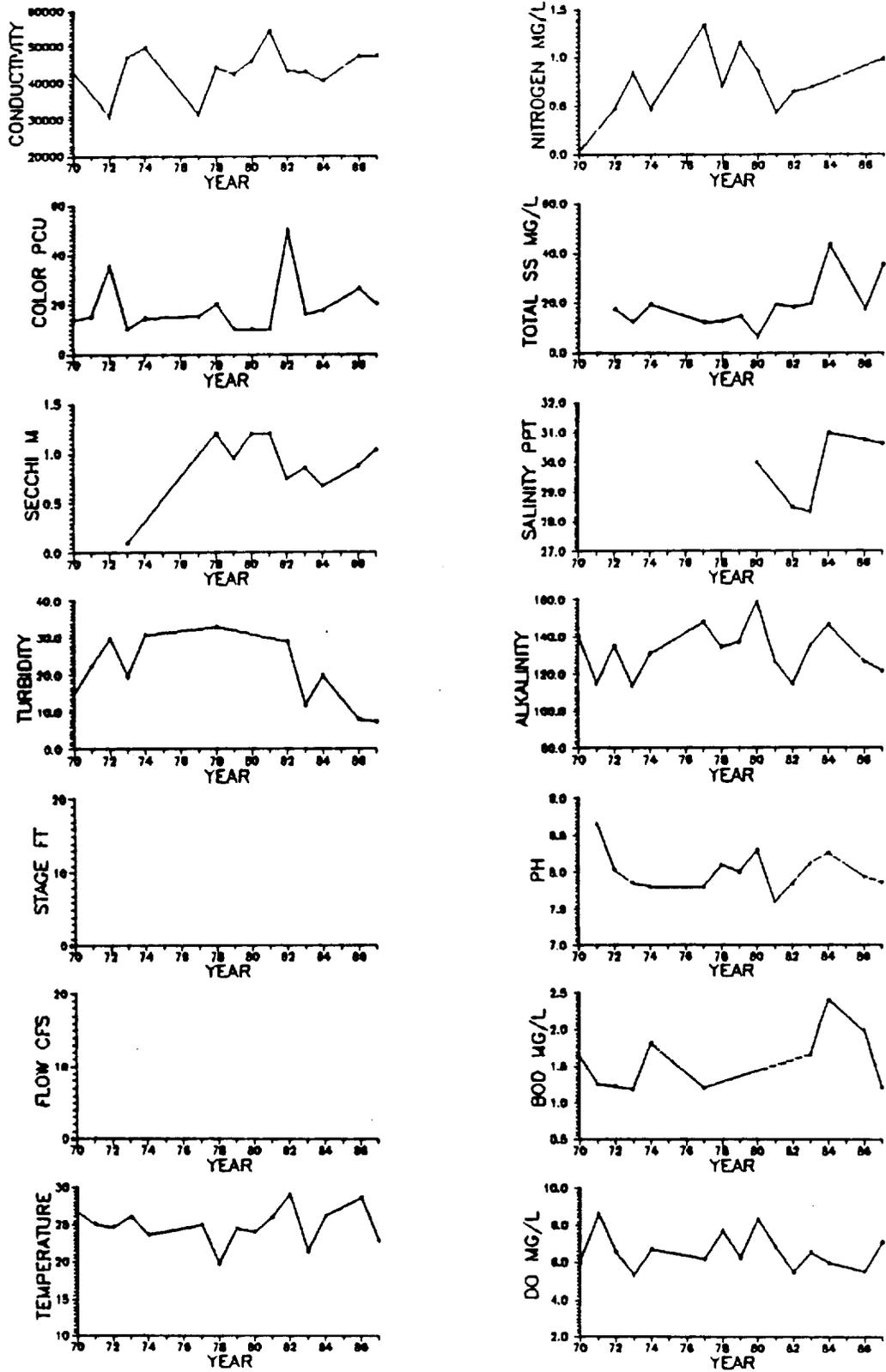


Figure 14. Summary of STORET Water Quality Data for Samples Collected between 1970 and 1987 from the New Smyrna and Edgewater Region of Mosquito Lagoon (Hand et al. 1988).

MOSQUITO LAGOON ABOVE ICWW CAT: 03080202 REACH: 1.00

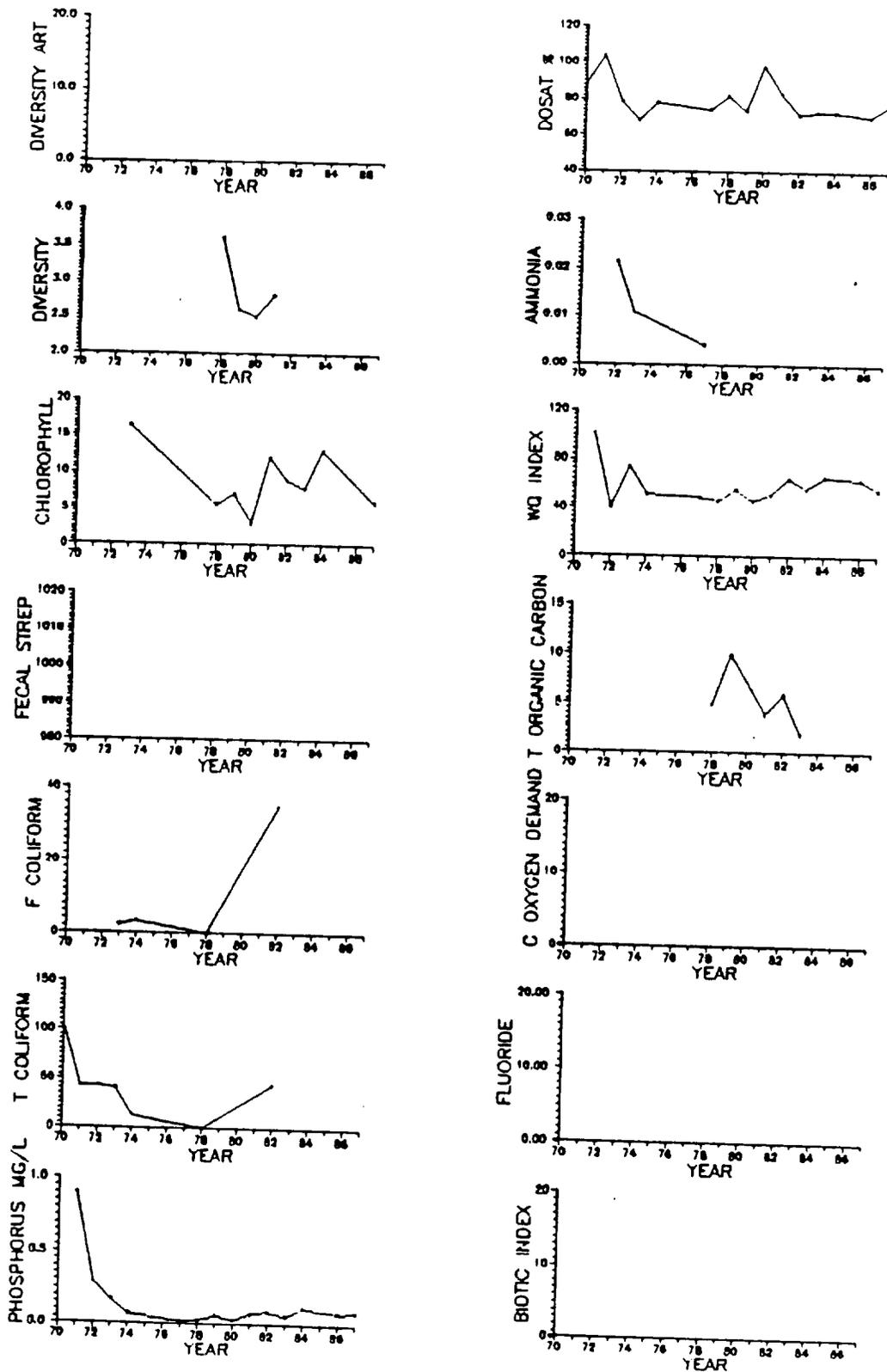


Figure 14 (continued). Summary of STORET Water Quality Data for Samples Collected between 1970 and 1987 from the New Smyrna and Edgewater Region of Mosquito Lagoon (Hand et al. 1988).

Table 6. Examples of Mosquito Lagoon Water Quality Data Available from STORET for Select Parameters.

Haulover Canal at SR3 Bridge, Station # 27010463 (Figure 15, #2)  
 Latitude/Long: 28° 44" 10.4 / 80° 45" 17.5

	Number	Mean	Beg. Date	End Date
Color (PT-CO Units)	7	20	1/29/74	7/20/87
Salinity (PPT)	6	28.5	12/7/83	7/20/87
TKN (mg/L)	8	1.34	10/9/73	7/20/87
NO <sub>2</sub> & NO <sub>3</sub> N-Total (mg/L)	1	.05	4/14/87	4/14/87
Phos-Tot (mg/L P)	8	.06	10/9/73	7/20/87
Chloro A (mg/L)	1	.01	10/9/73	10/9/73
Phos-Dis Ortho (mg/L P)	1	.01	10/9/73	10/9/73

Indian River at ICWW CM 4, Station # 27010461 (Figure 15, #0)  
 Latitude/Long: 28° 53" 07.0 / 80° 50" 40.0

	Number	Mean	Beg. Date	End Date
Color	7	19	10/29/74	7/20/87
Salinity	6	29.9	12/7/83	7/20/87
TKN	8	.92	10/9/73	7/20/87
NO <sub>2</sub> & NO <sub>3</sub> N-Total	1	.04	1/5/87	1/5/87
Phos-Tot	8	.09	10/9/73	7/20/87
Chloro A	1	.01	10/9/73	10/9/73
Phos-Dis Ortho	1	.02	10/9/73	10/9/73

Indian River at ICWW CM 21, Station # 27010467 (Figure 15, #5)  
 Latitude/Long: 28° 49" 08.0 / 80° 47" 59.0

	Number	Mean	Beg. Date	End Date
Color	6	19	12/7/83	7/20/87
Salinity	6	30.0	12/7/83	7/20/87
TKN	6	1.37	12/7/83	7/20/87
NO <sub>2</sub> & NO <sub>3</sub> N-Total	6	.02	12/7/83	7/20/87
Phos-Tot	6	.09	12/7/83	7/20/87
Chloro A (UG/L corrected)	5	9.29	12/7/83	7/20/87

Table 6. (continued)

Indian River at ICWW CM 50 Near Edgewater, Station # 27010466 (Figure 15, #18)  
 Latitude/Long: 28° 59" 38.0 / 80° 54" 12.0

	Number	Mean	Beg. Date	End Date
Color	6	19	12/7/83	7/20/87
Salinity	6	31.9	12/7/83	7/20/87
TKN	6	.85	12/7/83	7/20/87
NO <sub>2</sub> & NO <sub>3</sub> N-Total	1	.01	12/7/83	7/20/87
Phos-Tot	6	.10	12/7/83	7/20/87
Chloro A (UG/L corrected)	5	8.20	12/7/83	7/20/87

Indian River at ICW CM 45, Station # 27010451  
 Latitude/Long: 29° 00" 51.0 / 80° 54" 47.7

	Number	Mean	Beg. Date	End Date
Color	8	22	6/2/70	7/20/87
Salinity	6	31.1	12/7/83	7/20/87
TKN	6	.71	12/7/83	7/20/87
NO <sub>2</sub> & NO <sub>3</sub> N-Total	1	.02	12/7/83	7/20/87
Phos-Tot	6	.10	12/7/83	7/20/87
Chloro A (UG/L corrected)	5	8.36	12/7/83	7/20/87
Phos-Tot Ortho	1	.05	12/13/72	12/13/72

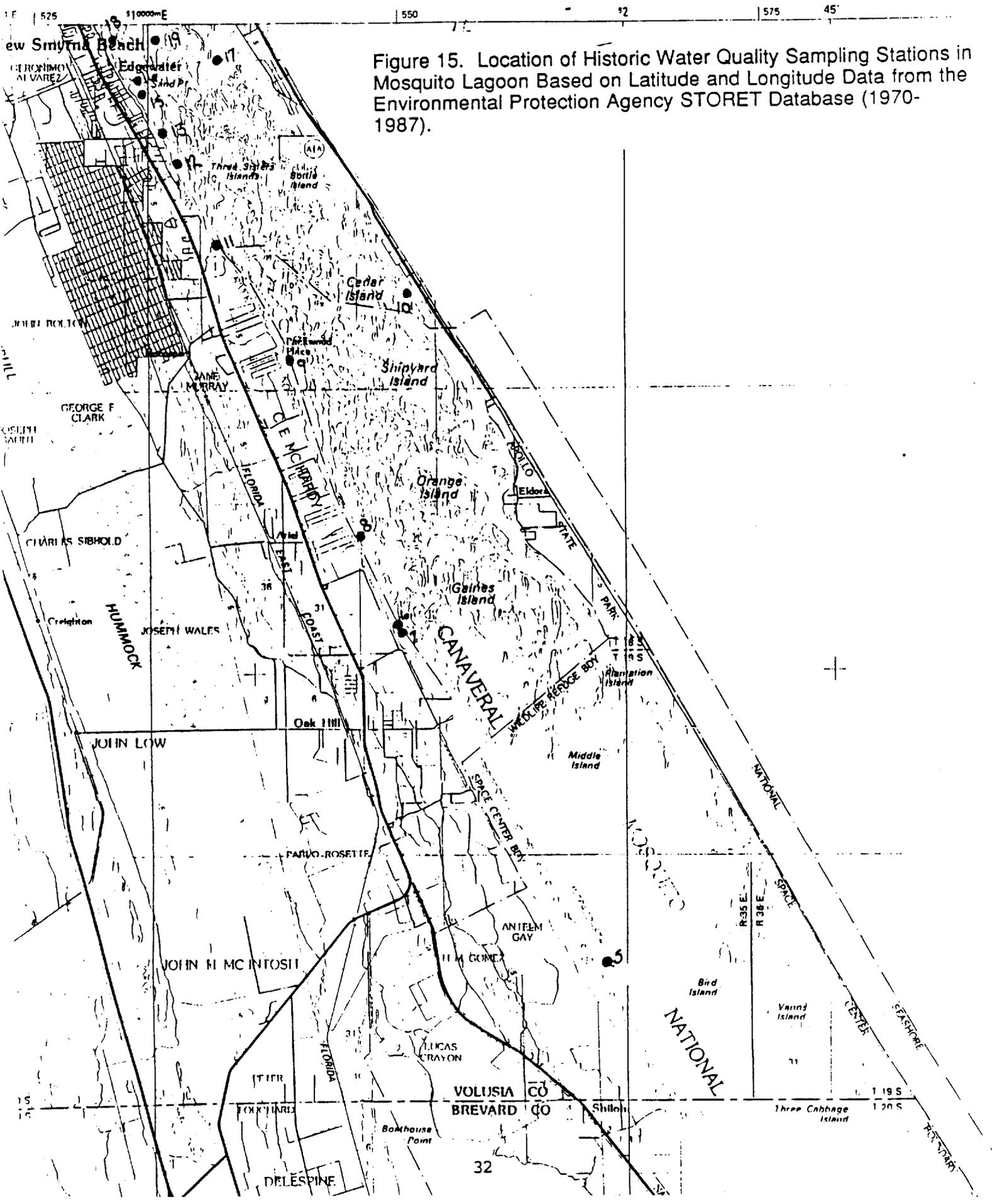
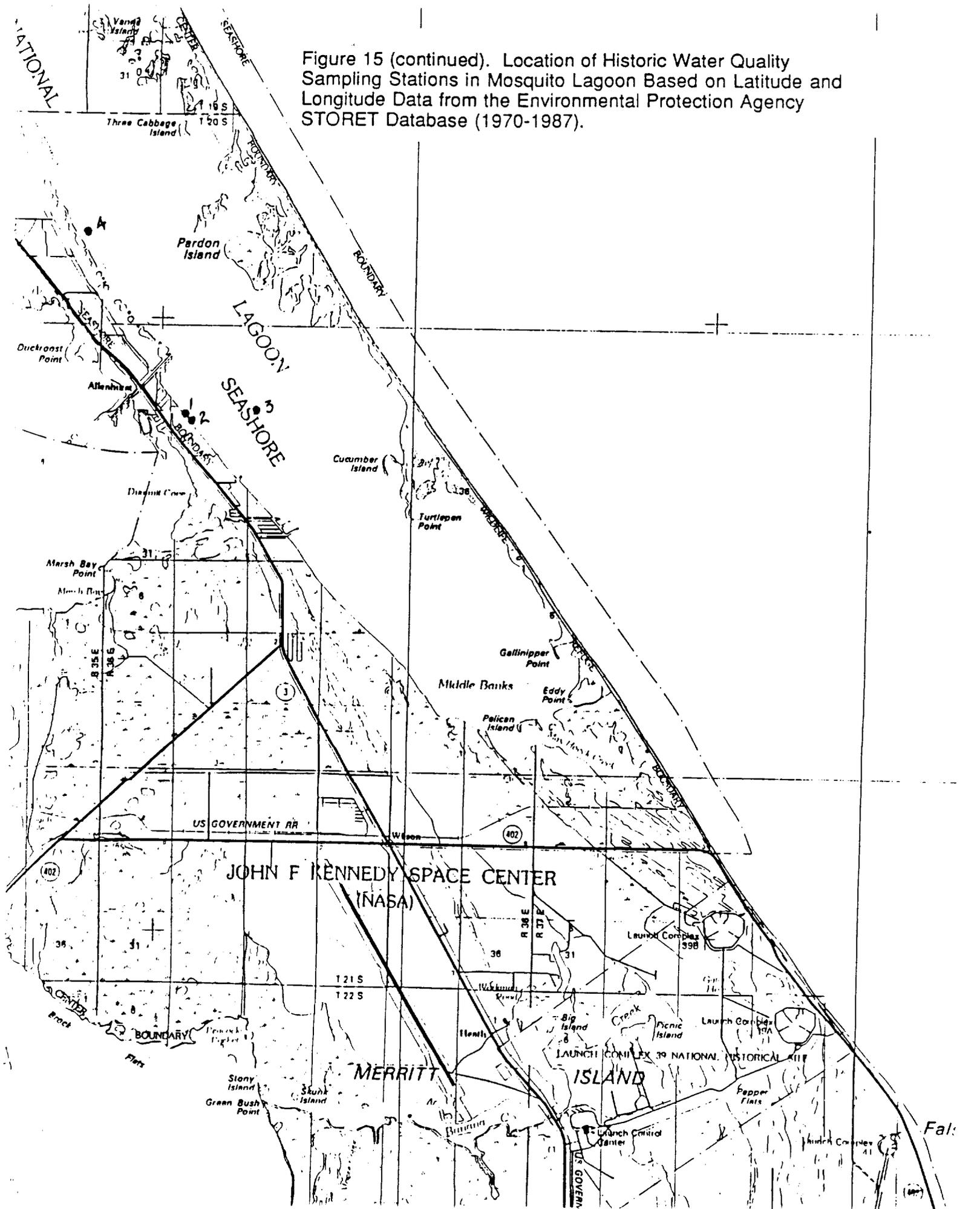


Figure 15. Location of Historic Water Quality Sampling Stations in Mosquito Lagoon Based on Latitude and Longitude Data from the Environmental Protection Agency STORET Database (1970-1987).

Figure 15 (continued). Location of Historic Water Quality Sampling Stations in Mosquito Lagoon Based on Latitude and Longitude Data from the Environmental Protection Agency STORET Database (1970-1987).



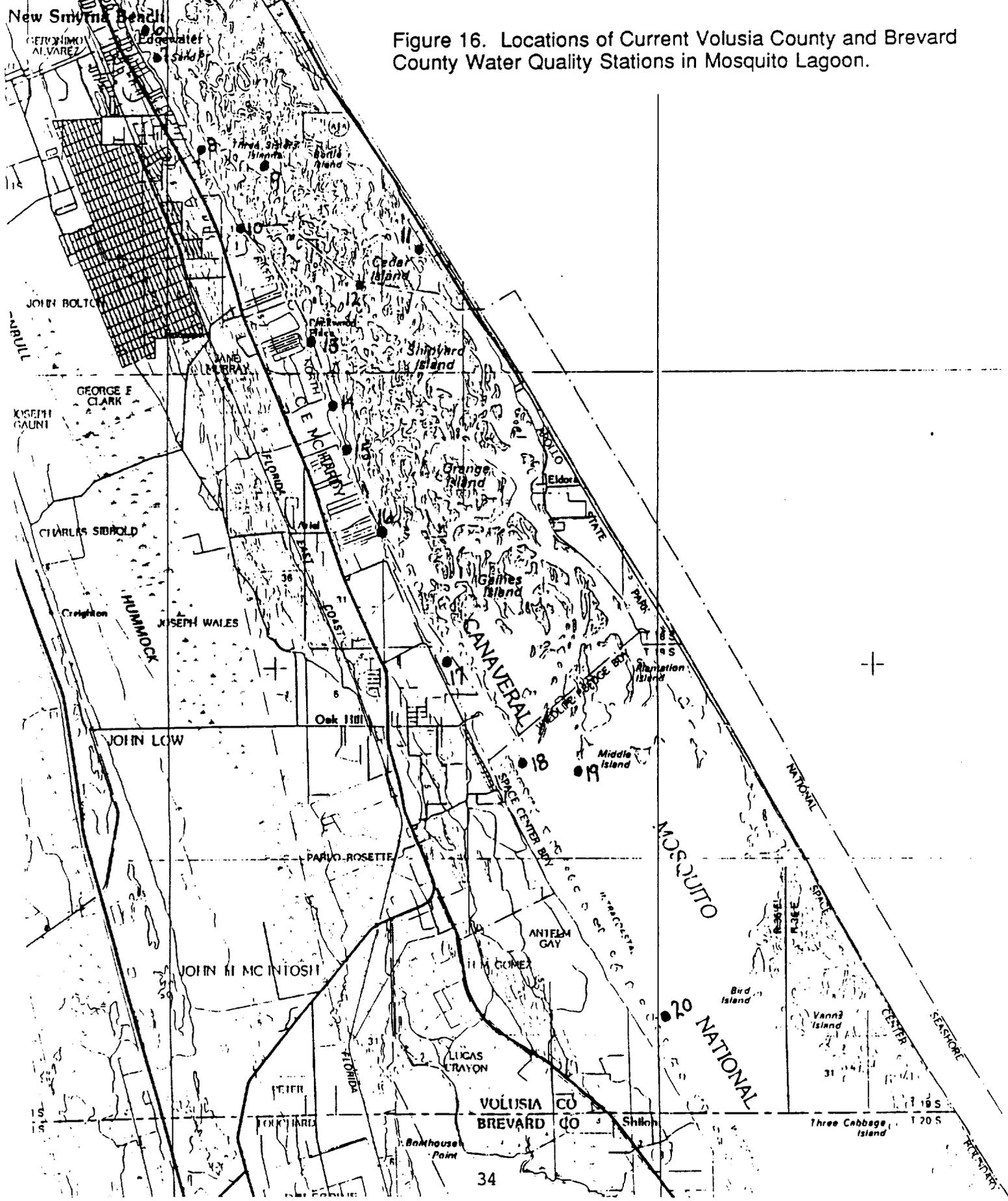


Figure 16. Locations of Current Volusia County and Brevard County Water Quality Stations in Mosquito Lagoon.

Figure 16 (continued). Locations of Current Volusia County and Brevard County Water Quality Stations in Mosquito Lagoon.

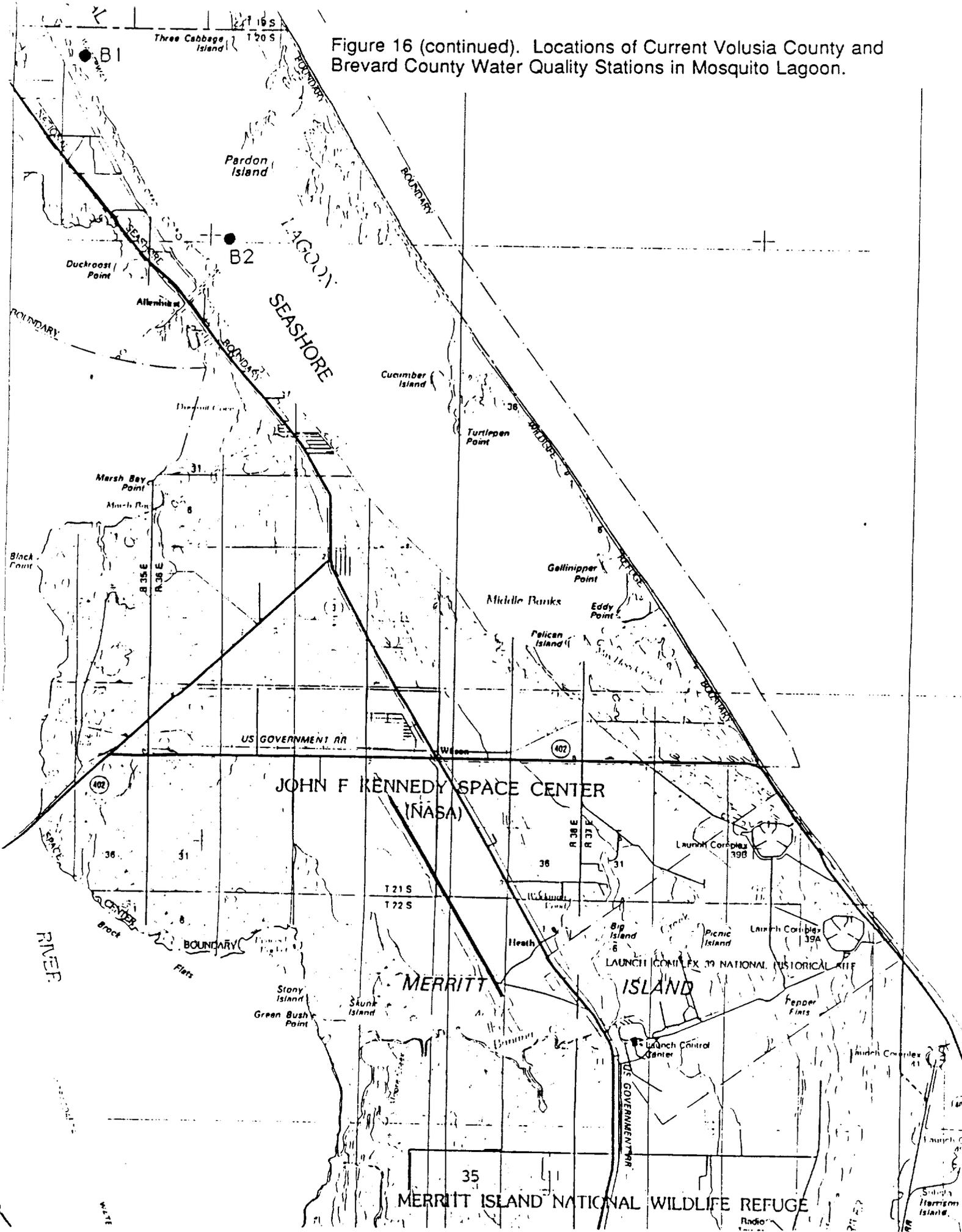


Table 7. Mean Values of Water Quality Parameters from Samples Collected at Twenty Stations October 1988 and March 1990. Data Provided by Volusia County Environmental Management.

Station	Chla	Pheo-A	Total Coliform	Fecal Coliform	Monthly Averages						Phos-Ortho	Phos-Total	Solids	DO	Nitro-TKN	Nitro-No2
					Fecal Strept	Entro-Cocci	Fecal Coliform	Fecal Strept	Entro-Cocci	Phos-Total						
1	5.21	4.75	31.25	13.11	36.59	21.42	0.10	0.02	6.21	4.68	0.60	0.01				
2	5.24	5.08	25.01	15.08	50.80	15.28	0.08	0.02	7.15	5.01	0.58					
3	7.44	26.73	32.72	20.45	44.95	13.94	0.08	0.02	7.04	4.40	0.86					
4	4.76	6.24	22.22	14.78	68.37	18.27	0.09	0.03	7.18	4.48	0.96					
5	5.22	6.13	23.50	16.93	70.94	18.05	0.09	0.02	7.64	4.48	0.98					
6	7.20	6.22	26.02	15.54	49.14	18.95	0.09	0.02	7.47	4.68	0.92					
7	6.81	7.30	27.43	13.86	53.51	25.36	0.08	0.03	6.35	4.65	0.98					
8	9.07	5.32	22.47	14.96	62.85	31.62	0.08	0.03	7.76	4.58	0.96					
9	4.90	7.49	12.59	10.85	80.91	18.01	0.08	0.03	7.11	6.77	0.91					
10	7.01	6.34	19.12	11.98	72.17	28.89	0.07	0.03	7.15	5.06	1.02					
11	5.01	3.43	23.93	14.26	32.58	15.68	0.08	0.04	8.40	6.07	1.18					
12	5.70	5.51	19.99	10.00	47.32	17.31	0.07	0.03	7.72	5.87	1.03					
13	5.76	5.27	13.76	11.57	48.52	18.86	0.06	0.02	7.60	4.48	0.97					
14	6.39	5.74	17.75	11.30	39.68	19.11	0.07	0.02	6.03	4.51	1.06					
15	5.37	4.63	13.91	12.59	51.14	24.94	0.07	0.02	6.39	4.33	1.06					
16	4.27	5.36	13.88	11.68	32.53	15.57	0.06	0.03	5.56	4.32	0.94					
17	4.56	4.33	11.88	10.85	31.80	14.42	0.06	0.02	6.31	4.47	0.96					
18	5.74	4.01	10.21	12.79	19.52	20.23	0.06	0.02	6.98	4.50	1.04					
19	3.01	3.11	7.80	10.00	11.53	17.72	0.05	0.02	4.61	4.78	1.07					
20	6.69	3.07	5.80	10.00	9.19	13.89	0.05	0.02	5.98	4.76	1.02					

Sleister (1989) reported on a sediment chemistry study designed to evaluate the impacts of stormwater discharge on total metal concentrations in Mosquito Lagoon. Results are presented in Figures 17 to 19. Elevated concentrations of lead, copper, and zinc were found in the vicinity of New Smyrna Beach and zinc was elevated near Edgewater.

Temperature fluctuations in Mosquito Lagoon display two distinct periodicities. On a daily basis water temperatures at a given location fluctuate in direct response to solar radiation, contact with the atmosphere as it warms and cools and the degree of internal mixing. Results of hourly temperature monitoring during a three week period in November 1988 are shown in Figure 20 for sites in the Indian River, Banana River and Mosquito Lagoon. The external controlling factor of meteorology produces similar responses in all surface waters in this region. During fall, daily temperatures gradually decline in response to decreasing solar radiation and cooling air temperatures. Mean monthly maximum air temperatures in summer (June, July, and August) is 32°C. Mean monthly air temperature in winter (December, January, and February) is 21°C. Differences in water temperatures between day and night average about 3°C (Figure 20) compared to daily average air temperature fluctuations of 7°C.

The passage of periodic weak cold fronts during late fall produces steep declines in water temperatures (Figure 20). During winter, the passage of more intense cold fronts dominate the variability observed in surface water temperatures. This is shown graphically in Figure 21 which presents water temperatures for the same time period during two different years. Strong north winds (rapid mixing) and declining air temperatures during December of 1989 combined to reduce water temperature to near the freezing point (3 to 4°C) in a matter of hours. This rapid decline put stress on the warm temperate and subtropical biotic systems leading to fish kills and extensive vegetation damage around Mosquito Lagoon and KSC. As shown in Figure 21, between year variability for a given time period can be large. On December 25, 1988 water temperatures were 15°C warmer than in 1989.

During spring, water temperatures gradually rise to the mid 20s and low 30s where they typically remain throughout summer. Daily fluctuations in water temperatures during this period average about 3°C. Hourly temperatures for a four week period in late May and early June are shown in Figure 22.

During summer, shallow confined areas may become extremely hot, with temperatures exceeding 34°C. This is most common in shallow areas of impoundments and along the shoreline of the lagoons shoreward of the grass flats during summer periods of low water. High temperatures in association with large amounts of decaying organic matter Biological Oxygen Demand (BOD) often result in a decline in dissolved oxygen which, in turn, can produce a summer fish kill. These conditions have been observed in Banana Creek near the State Road 3 bridge and along shallow shorelines of the Banana River segment including the Hangar AF area. Figure 23 shows hourly dissolved oxygen levels recorded during a two day period following a fish kill in Banana Creek on July 17, 1984. Minimum concentrations (0.02 mg/l) occurred during the morning hours when system respiration (oxygen consumption) exceeded primary production (oxygen production). Relatively high dissolved oxygen concentrations (7.80 mg/l) were produced during afternoon hours only to be reduced to lethal levels

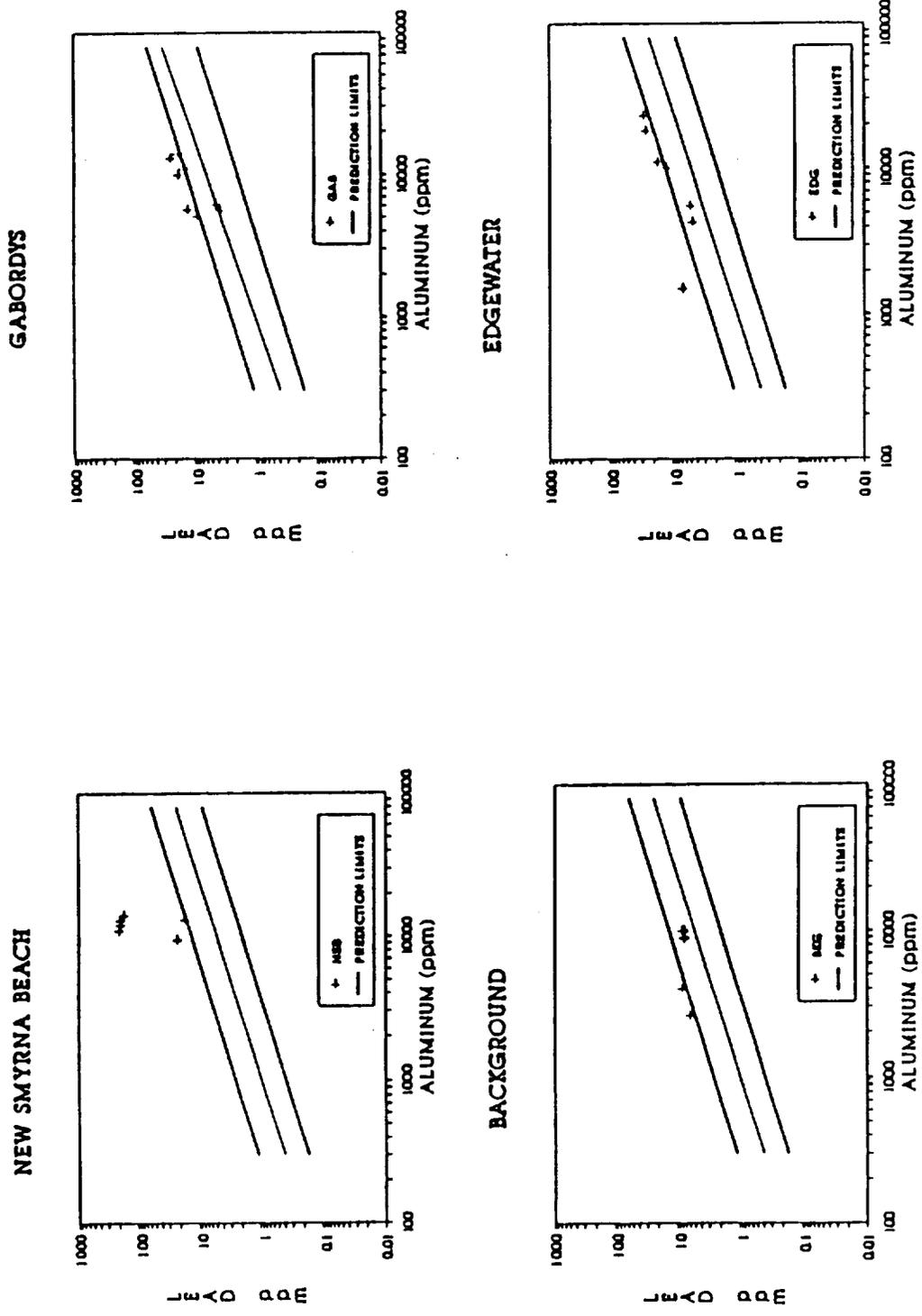


Figure 17. Results of Sediment Chemistry Analyses for Lead at Four Different Locations in Mosquito Lagoon. Data Values that Occur above the Expected Relationship with Aluminum Suggest the Presence of Pollution.

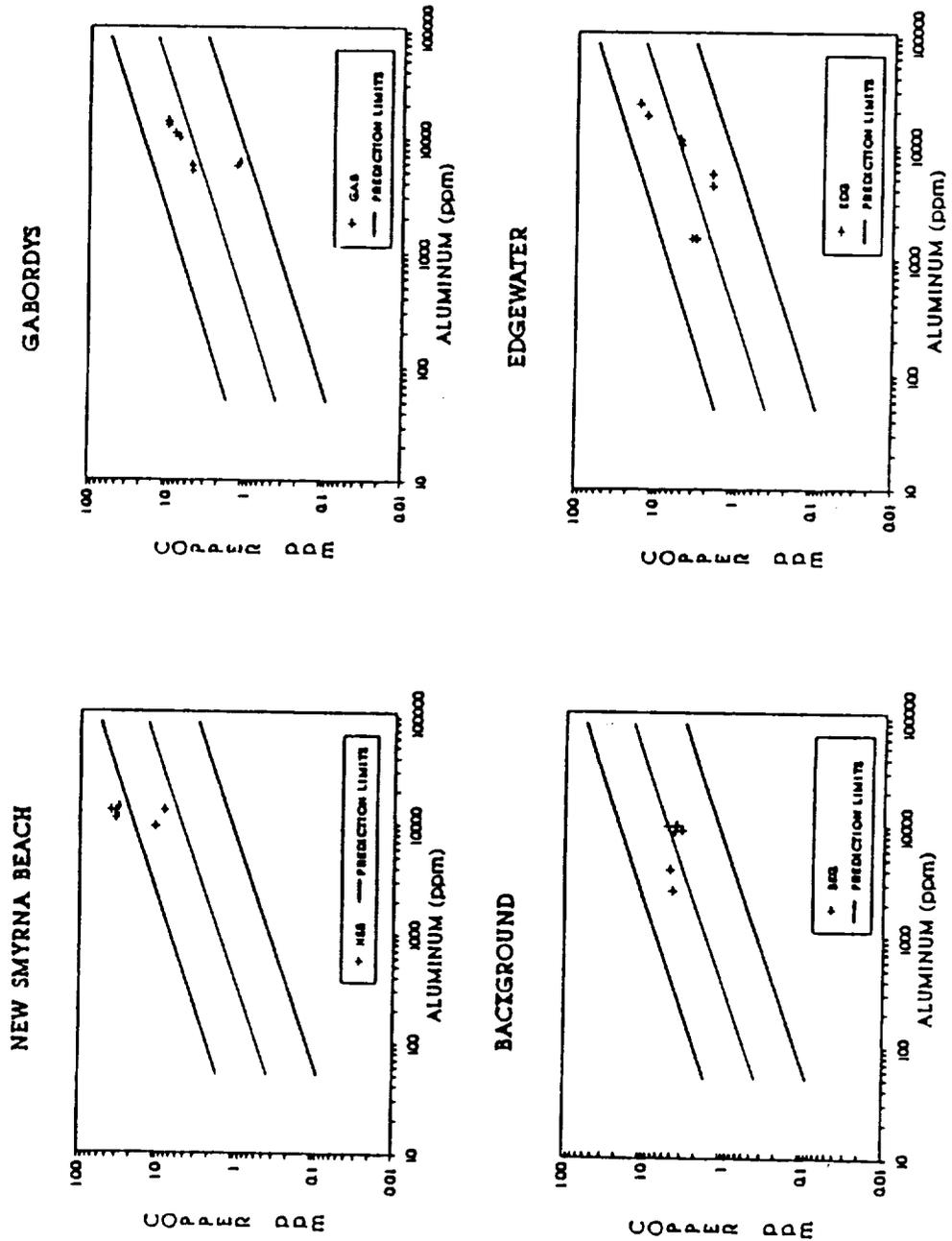


Figure 18. Results of Sediment Chemistry Analyses for Copper at Four Different Locations in Mosquito Lagoon. Data Values that Occur above the Expected Relationship with Aluminum Suggest the Presence of Pollution.

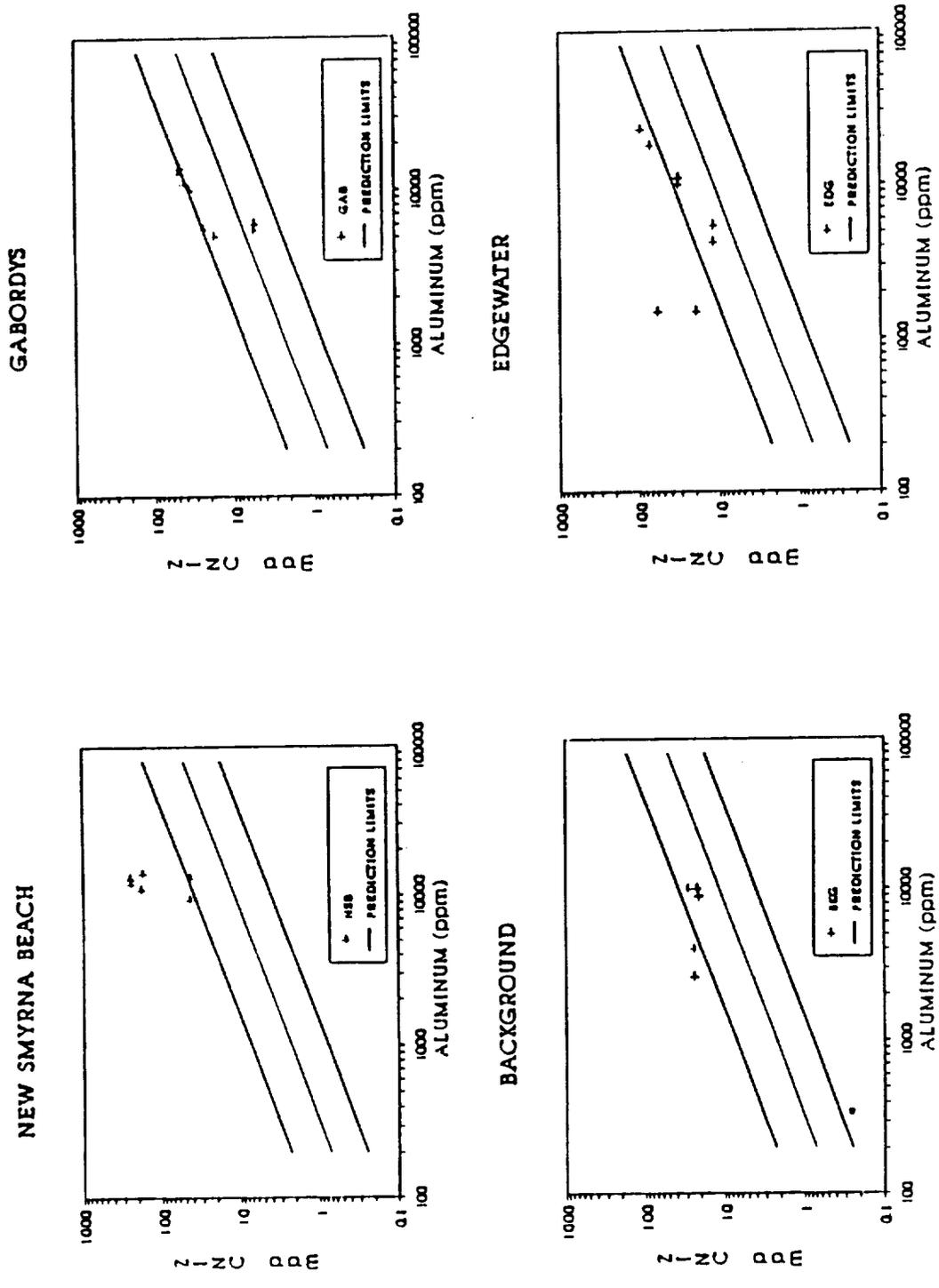


Figure 19. Results of Sediment Chemistry Analyses for Zinc at Four Different Locations in Mosquito Lagoon. Data Values that Occur above the Expected Relationship with Aluminum Suggest the Presence of Pollution.

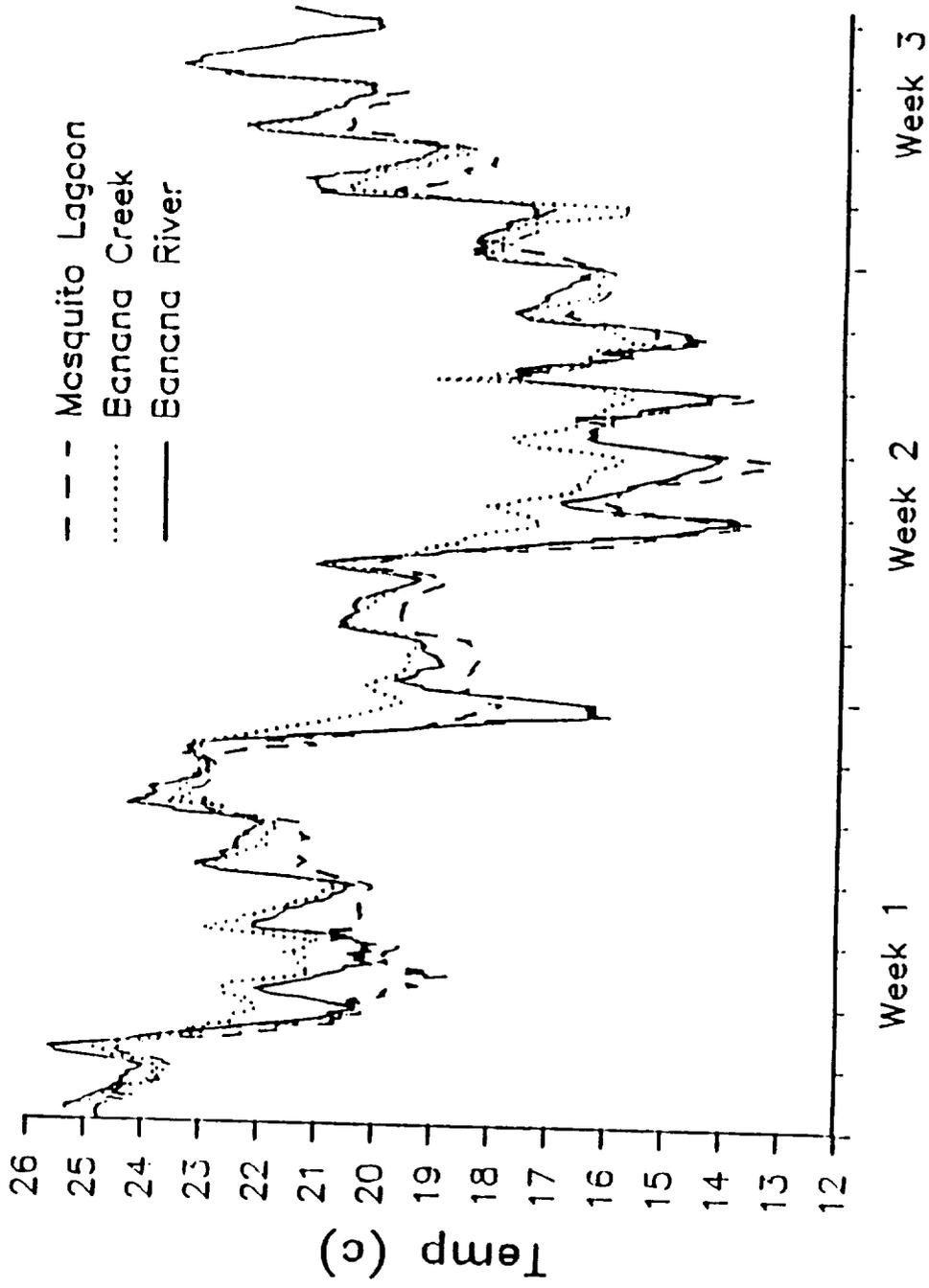


Figure 20. Results of Hourly Temperature Monitoring for a Three Week Period beginning November 1988 in Mosquito Lagoon, Banana Creek, and Banana River.

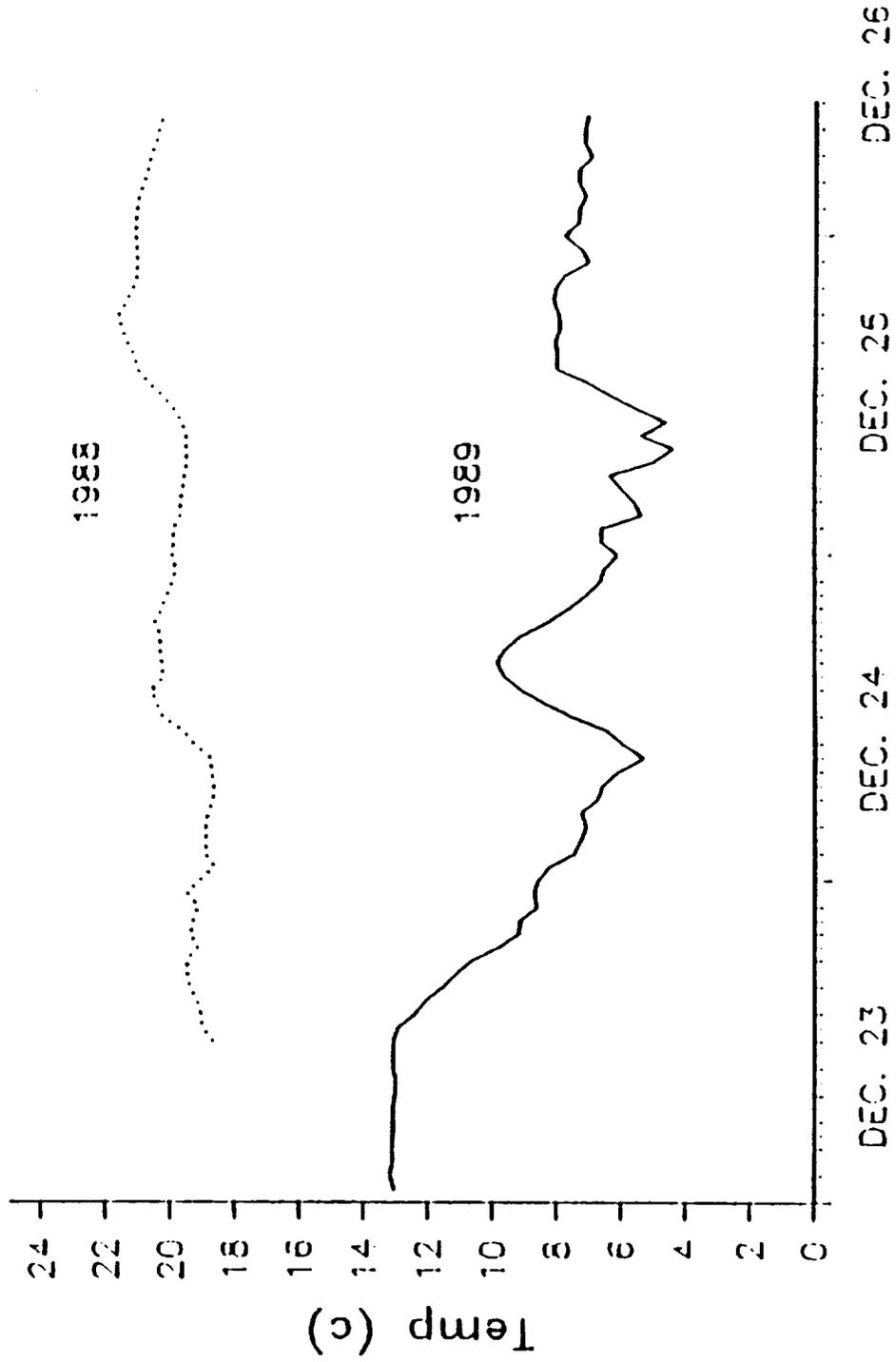


Figure 21. Results of Hourly Temperature Monitoring for a Three Day Period in December 1988 and December 1989.

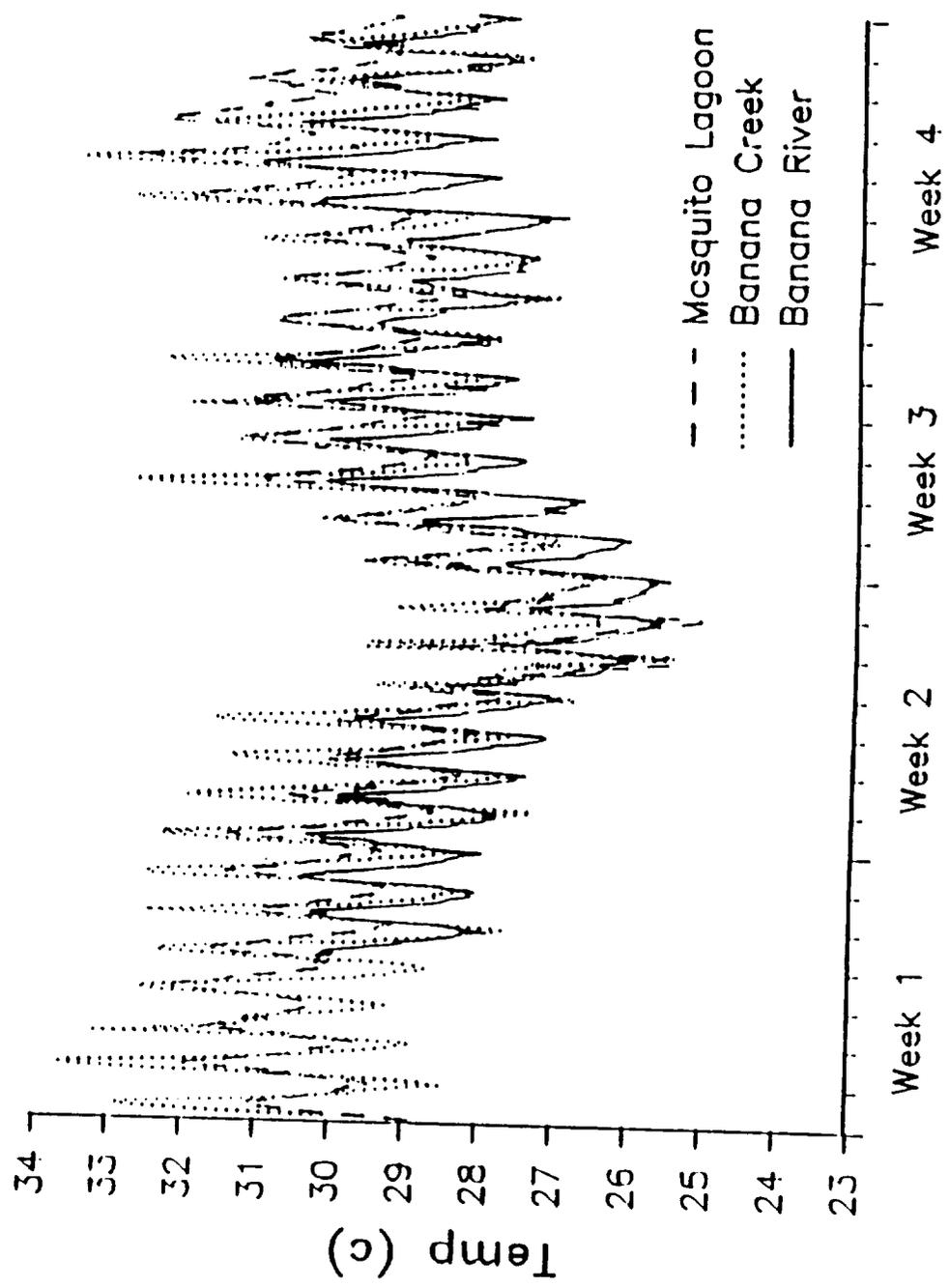


Figure 22. Results of Hourly Water Temperature Monitoring for a Three Week Period beginning May 1989 in Mosquito Lagoon, Banana Creek, and Banana River.

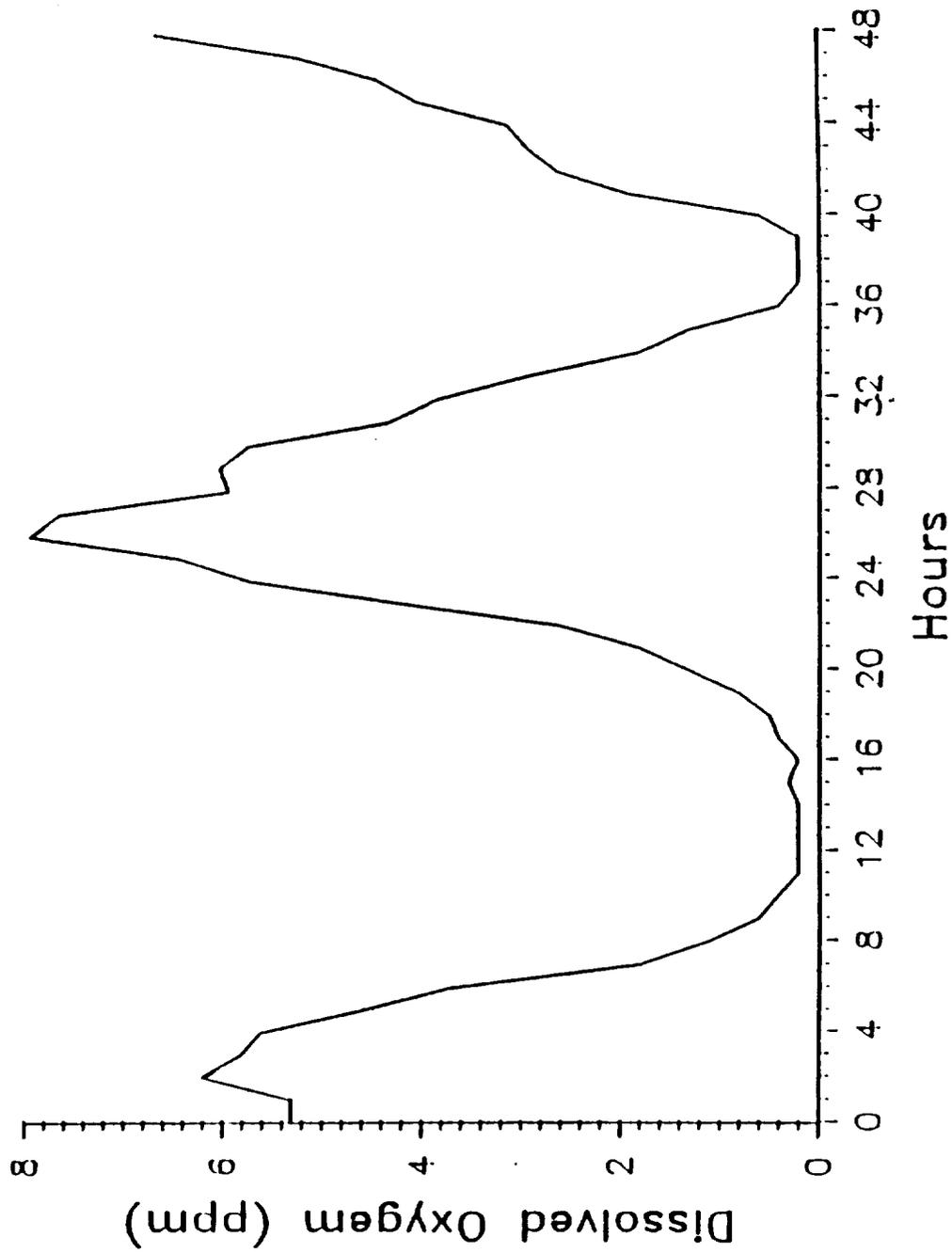


Figure 23. Results of Hourly Dissolved Oxygen Monitoring during a 48 Hour Period following Observation of a Major Fish Kill in Banana Creek on July 17, 1984.

(< 1.0 mg/l) during night and early morning by the high BOD. Over time (3 to 5 days) the BOD may be satisfied and the system returns to a more stable set point.

In general, dissolved oxygen concentrations observed during routine water quality monitoring are sufficiently elevated to sustain the biotic communities. Values typically range between 5.5 and 8.5 mg/l. Samples collected in the vicinity of dense SAV on occasion display supersaturation with values above 13 mg/l being observed as a result of high primary production occurring in these areas. Transient low dissolved oxygen levels (< 2.0 mg/l) and anaerobic conditions have been observed in isolated areas of impoundments, roadside ditches, and swales. In every case these conditions appeared to be the result of high BOD resulting from the decay of detritus and vegetation.

Results of monthly water level and salinity measurements for Mosquito Lagoon, Banana Creek, and Banana River are shown in Figure 24 and 25. Water levels in the lagoon system display a very distinct pattern when measured on a monthly basis with peaks in late fall and minimums in summer. This pattern corresponds to the annual rise and fall in sea level with all three lagoons averaging approximately 6-7 in (15-18 cm) above mean sea level. Not apparent in these data are the short term wind-driven fluctuations that may occur over a period of days. Smith (1990) describes the results of field and modeling studies of non-tidal circulation for the Indian River Lagoon. Wind driven set-up of waters in the south end of Mosquito Lagoon occurs when winds blow from a northerly direction. This wind correspondingly sets-down waters in the north end of the Indian River producing a water-level difference between the two systems that results in significant non-tidal exchange through Haulover Canal. This pattern is reversed when winds blow from the south-southwest. Wind driven set-up of waters also produces a significant bottom layer flow pattern upwind as a result of barotropic pressure gradients. This near-bottom flow can be especially large in the deep channels and Intercoastal Waterway (ICWW).

Mosquito Lagoon is typically more saline than other reaches of the Indian River Lagoon System and hyper-saline (> 35 ppt) conditions are not uncommon during dry spring and early summer months when evapotranspiration exceeds rainfall. Salinity has averaged about 32 ppt during the last six years and there appears to be an increasing trend in the data for both Mosquito Lagoon and the Banana River. This increase may be directly related to low rainfall during 1988-1990. Salinities in Banana Creek are much more variable than the open lagoon ranging from a low of 1 ppt to a high of 34 ppt. A comparison of water level and salinity data from two mosquito impoundments (T-24-D and T-27-C) are presented in Figures 26 and 27. Impoundment T-27-C is located north of Launch Pad 39B at the south end of Mosquito Lagoon and is considered a brackish marsh system. Water levels and salinities fluctuate widely with maximum salinities (> 40 ppt) occurring during periods of extreme low water levels which are controlled by rainfall and evapotranspiration. Impoundment T-24-D is a fresh water marsh system located on the western side of Merritt Island. Water levels in the fresh water systems are typically higher than the brackish systems and salinities rarely exceed 10 ppt.

Results of chemical analyses are summarized in Tables 8 and 9 for Mosquito Lagoon and Max Hoeck Back Creek. Several parameters, including phenols, silver, iron and

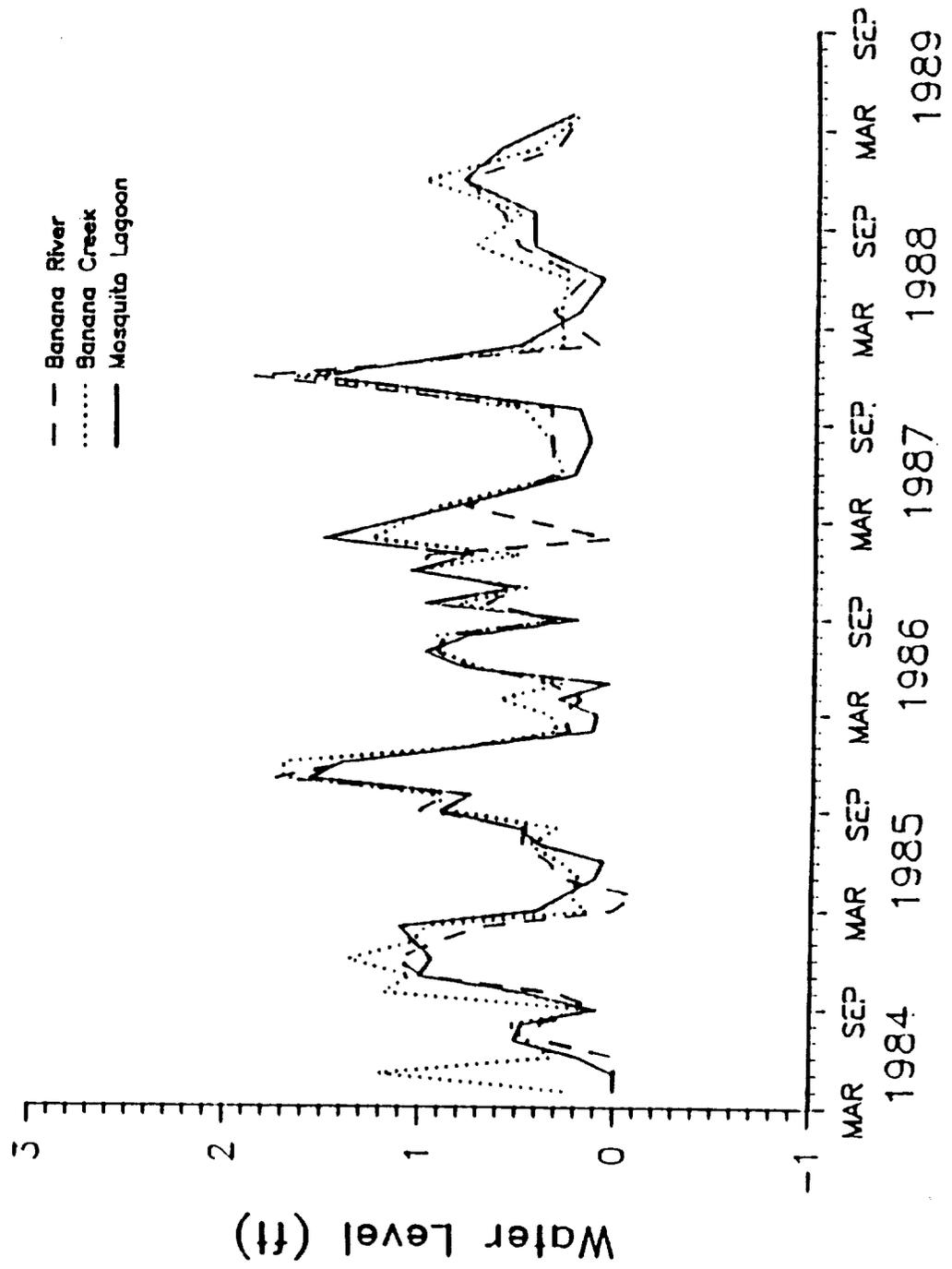


Figure 24. Results of Monthly Water Level Monitoring by the U.S. Fish and Wildlife Service in Mosquito Lagoon, Banana Creek, and Banana River between 1984 and 1989.

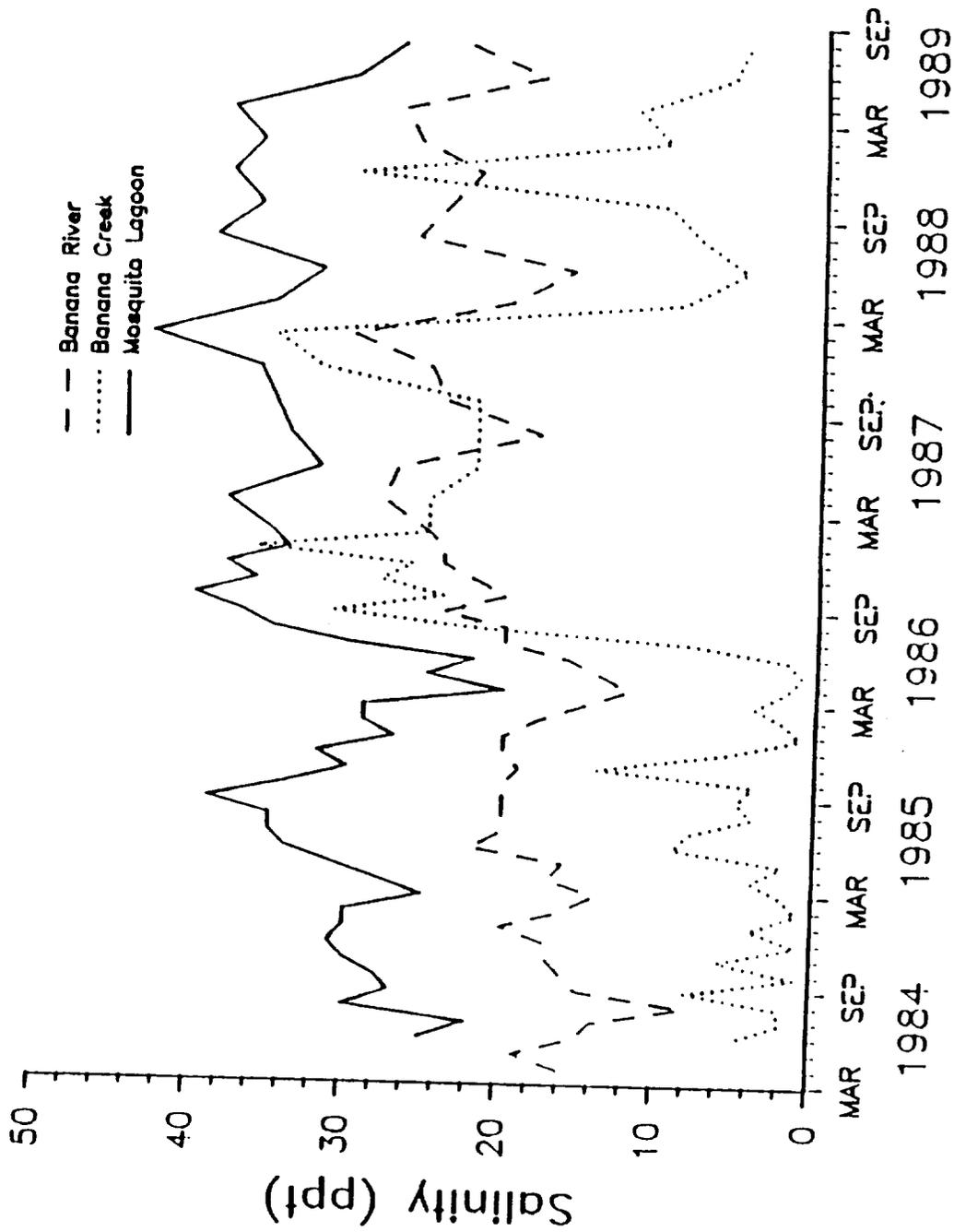


Figure 25. Results of Monthly Salinity Monitoring by the U.S. Fish and Wildlife Service in Mosquito Lagoon, Banana Creek, and Banana River between 1984 and 1989.

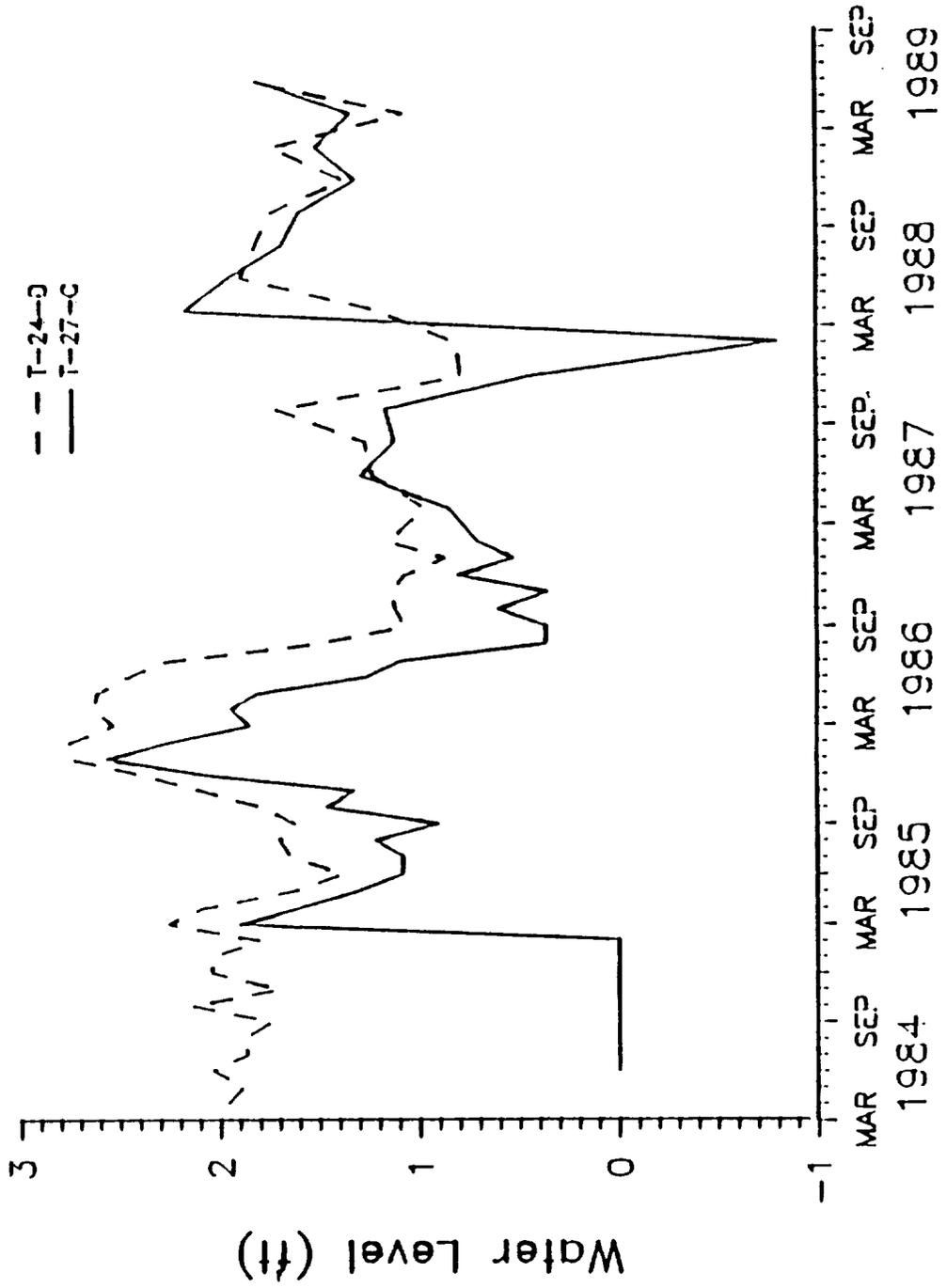


Figure 26. Results of Monthly Water Level Monitoring by the U.S. Fish and Wildlife Service in a Fresh and a Brackish Mosquito Impoundment on Merritt Island between 1984 and 1989.

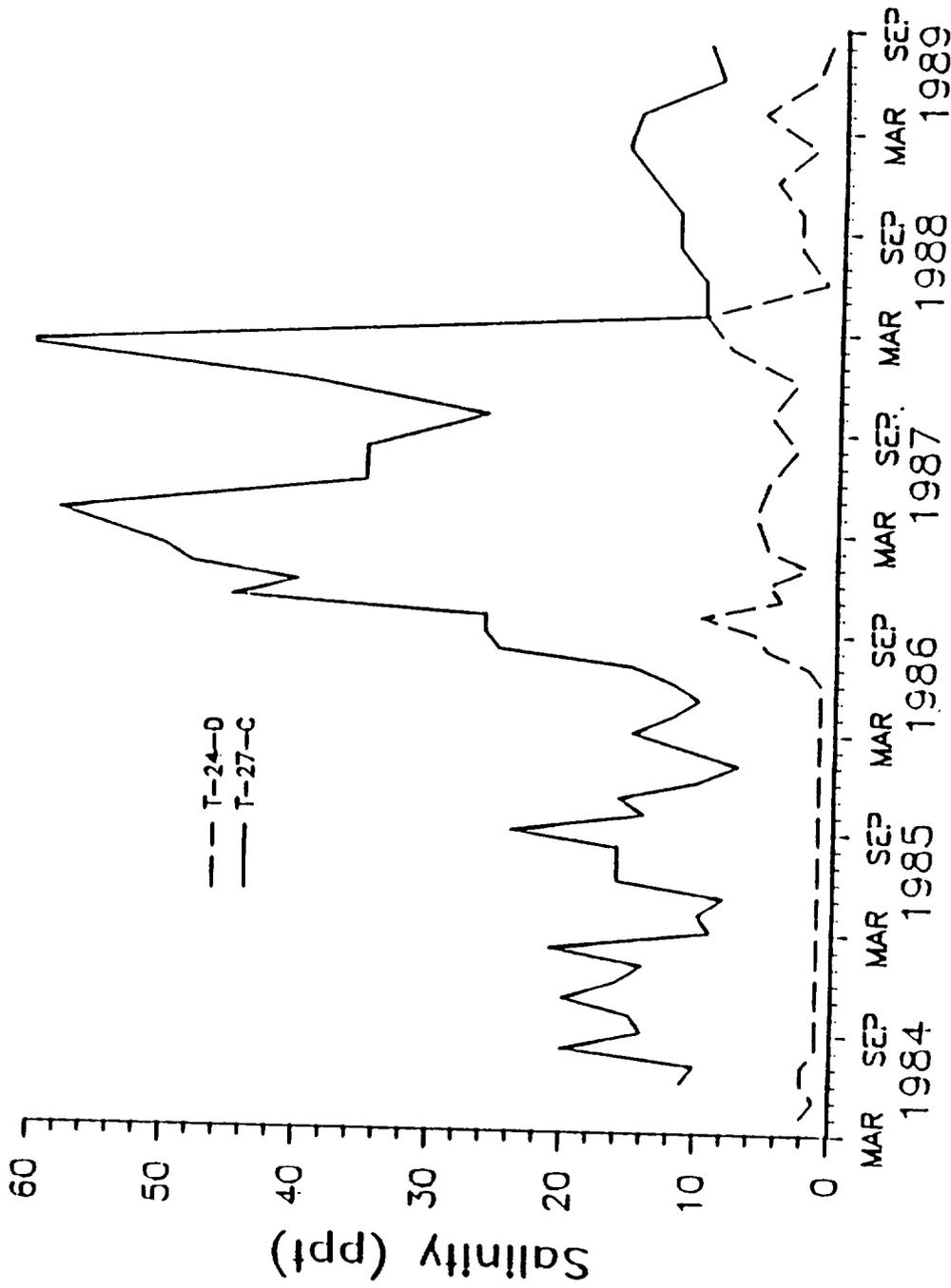


Figure 27. Results of Monthly Salinity Monitoring by the U.S. Fish and Wildlife Service in a Fresh and a Brackish Mosquito Impoundment on Merritt Island between 1984 and 1989.

Table 8. Summary of Water Quality Monitoring Data for South Mosquito Lagoon between 1985 and 1990.

Parameter	Average	Minimum	Maximum
Conductivity ( $\mu\text{mhos/cm}$ )	45200	25200	62200
Total Suspended Solids (mg/l)	68	9	655
Turbidity ntu	5.5	2.0	20.0
Oil and Grease (mg/l)	0.4	<0.2	4.3
Phenols ( $\mu\text{g/l}$ )	178	<5	678
Alkalinity (mg/l)	145	84	349
pH	8.4	7.5	8.8
Total Kjeldahl Nitrogen (mg/l)	1.41	0.39	3.25
Nitrate Nitrogen (mg/l)	0.03	<0.02	0.06
Ortho Phosphate (mg/l)	0.029	<0.025	0.100
Chlorophyll A ( $\text{mg/m}^3$ )	5.1	<0.5	64.7
Biological Oxygen Demand (mg/l)	3.5	<1.0	17.0
Chemical Oxygen Demand (mg/l)	656	225	1732
Dissolved Oxygen (mg/l)	5.7	2.0	10.4
Total Organic Carbons (mg/l)	4.42	0.98	28.1
Aluminum (mg/l)	0.26	<0.10	0.50
Cadmium ( $\mu\text{g/l}$ )	0.70	<0.10	2.95
Chromium (mg/l)	0.004	<0.001	0.008
Iron (mg/l)	0.190	<0.040	0.386
Zinc (mg/l)	0.02	<0.01	0.08
Silver ( $\mu\text{g/l}$ )	5.86	<0.05	44.00

Table 9. Summary of Water Quality Monitoring Data for Max Hoeck Back Creek (Mosquito Impoundment) between 1985 and 1990.

Parameter	Average	Minimum	Maximum
Conductivity ( $\mu\text{mhos/cm}$ )	29500	12000	75000
Total Suspended Solids (mg/l)	63.8	<1.0	385
Turbidity NTU	11.6	0.6	35.5
Oil and Grease (mg/l)	0.60	<0.20	6.29
Phenols ( $\mu\text{g/l}$ )	110	<5	343
Alkalinity (mg/l)	180	48	412
pH	8.6	7.2	10.0
Total Kjeldahl Nitrogen (mg/l)	5.05	0.69	13.50
Nitrate Nitrogen (mg/l)	0.05	<0.02	0.10
Ortho Phosphate (mg/l)	0.090	<0.025	1.400
Chlorophyll A ( $\text{mg/m}^3$ )	9.5	<0.5	82.8
Biological Oxygen Demand (mg/l)	5.5	2.0	18.0
Chemical Oxygen Demand (mg/l)	725	172	1680
Dissolved Oxygen (mg/l)	7.3	0.0	13.2
Total Organic Carbons (mg/l)	13.3	2.6	39.4
Aluminum (mg/l)	0.95	<0.10	5.10
Cadmium ( $\mu\text{g/l}$ )	0.15	<0.01	3.00
Chromium (mg/l)	0.0045	<0.001	0.012
Iron (mg/l)	0.70	<0.04	3.65
Zinc (mg/l)	0.04	<0.01	0.12
Silver ( $\mu\text{g/l}$ )	14.04	<0.05	30.00

aluminum are consistently found at levels exceeding criteria of the Florida Department of Environmental Regulation surface water quality classifications (see Appendix E). The general phenol criteria represents a complex rule (Florida Administrative Code 17-3) that is designed to limit the levels of primarily man-made chlorinated phenolic compounds in state waters. The criteria is set at 1.0 ug/l and phenolic compounds other than those produced by the natural decay of plant material shall not taint the flesh of edible fish or shellfish or produce objectionable taste or odor in the drinking water supply. It is believed that the high levels of phenols observed in surface waters in this region are common decomposition products or humic materials derived from natural vegetation of the region.

High levels of total silver, in excess of the 0.05 ug/l criteria, have been observed in every body of water sampled at KSC. Average levels are generally two orders of magnitude above the criteria and no apparent source has been identified. Sea water commonly contains 0.3 ug/l in the open oceans. The levels reported appear to be indicative of background concentrations for the area based on their widespread distribution through isolated water bodies. The presence of high levels of humic material suggests that there may be some relationship between elevated silver and phenols through metal binding with high molecular weight organic fractions. More information on this possible problem needs to be gathered before a determination of the validity and significance of these results can be made.

A second metal that is frequently found at concentrations above the state criteria of 0.3 mg/l is iron. As with silver the wide spread distribution of iron suggests that baseline levels in waters of the region may be elevated above expected. Results of sediment chemistry indicate iron is commonly present in the 500 to 1000 mg/kg range. Iron is known to form flocculants in estuarine and marine environments and, as with other metals, there is a complex relationship between iron, pH, redox potential, and organic matter.

Maximum values recorded for aluminum in Max Hoeck Back Creek, Banana Creek, and Banana River were above the 1.5 mg/l criteria and these levels may be related to the amount of humic material present in the water column. Examination of the average data values for the other metals indicated no exceedances of any state criteria.

Results of nutrient analyses (nitrates, ammonia, and ortho-phosphate) revealed low values with few exceptions. The abundance of dense beds of SAV and the associated attached microalgae serve to control dissolved nutrients in the absence of a major man made source. Chlorophyll levels, an indicator of phytoplankton production, are also generally low suggesting that in most cases the majority of primary production occurring in the southern part of Mosquito Lagoon is associated with the SAV and attached microalgae. The partitioning of nutrients between seagrasses, macro-algae and phytoplankton is a complex issue and no quantitative information on the subject was found for Mosquito Lagoon. Lasater (1976) states that in spring and early summer the red macroalgae (Hypnea cervicornis) enters a rapid growth phase when water temperatures exceed 29°C. The consumption of dissolved nutrients can be so great that populations of phytoplankton are reduced producing a period of extreme water clarity. Lee and Olson (1985) report that in some lagoon systems nutrient enrichment results in growth of macroalgae instead of phytoplankton.

A second factor that controls the level of nutrients measured in the water column at any given time is the rate and efficiency of benthic nutrient regeneration (Nowicki and Nixon 1985). Benthic-pelagic coupling is extremely important because the volume of water overlying a given area of bottom in lagoonal systems is relatively small and the influence of benthic processes may be correspondingly large when compared to marine environments. Flint et al. (1985) indicated that 90% of the dissolved nitrogen needed for primary production in Corpus Christi Bay estuary was derived from benthic regeneration. In coastal areas beyond the barrier island this value dropped to 33% in water 15 m deep. No information on the benthic regeneration of nutrients in Mosquito Lagoon was found through the literature search.

Associated Database Reference numbers: 1, 3, 4, 7, 8, 9, 11, 12, 17, 36, 37, 39, 43, 58, 59, 61, 73, 83, 84, 88, 93, 94, 95, 96, 97, 105, 106, 107, 108, 111, 113, 116.

#### FISHES:

The entire Indian River Lagoon system (IRL) is known to be a major contributor to the Florida fishing industry. Landings data reviewed by Durako et al. (1988) showed that Mosquito Lagoon and the upper Indian River complex are the most productive areas for the northeast Florida coast region. The restricted circulation and often hypersaline conditions of Mosquito Lagoon lead to a reference to it as a "miniature ocean environment" whereby some fish species remain in the lagoon rather than migrate offshore to complete their life cycles. A list of fish species that may be encountered in Mosquito Lagoon is presented in Appendix F.

Concern for the potential decline of certain fish species inspired investigations as early as the 1890's (Brice 1897; Tabb 1960). Evermann and Bean (1897) and Wilcox (1897) provided an excellent review of the fish and fisheries in the Indian River Lagoon but with few references to Mosquito Lagoon (also known as the Hillsboro River). When the Florida East Coast Railroad came to Titusville in 1885, the town became an important supplier of fish to northern cities in and outside of Florida. Titusville had the largest fishery along the lagoon in 1890. Wilcox (1897) provided no description of main fishing grounds for Titusville landings but one would assume that some level of activity was taking place in Mosquito Lagoon.

Gilmore (in press) reviewed anecdotal information regarding Mosquito Lagoon, "Waters abound in fish... and mullet are remarkably abundant". Fishing in the 1870's was predominantly for family use. Mosquito Lagoon catches for export in 1879 consisted of "150 green turtles, 300-400 mullet roes and a few barrels of salt mullet". Unfortunately, very little information is available for the region between the mid 1890's and the 1950's.

Tabb (1960) reviewed the spotted seatrout fishery of the Indian River area in the early 1950's but gave little mention of Mosquito Lagoon. However, he did warn that fishery declines would be inevitable as increases in human population would lead to development of marginal shallows of the lagoon bringing with it pollution, bottom alteration, increased freshwater drainage and inlet construction. Anderson and Gehringer (1965) also mentioned concern for the ongoing alteration of the lagoons with

dredging and filling operations. They described the Cape Canaveral waters (including Mosquito Lagoon) as being some of the most productive in Florida with much of the bottom covered with vegetation that provided ideal habitat for a variety of fish. Their census provided a good synopsis of various fisheries in the Canaveral area with detailed statistics for many species but without specific locality data. They reviewed catches and estimated sport fishery efforts for the northern and then southern section of the Canaveral area. The northern section extended from Ponce de Leon Inlet south through Mosquito Lagoon to Indian River just north of the Titusville bridge. They found that about 30% of the fishermen in the north end were involved in bank fishing and a little less than 30% were fishing from boats. Fish catch per unit effort was 0.92 as compared to 1.17 in the southern section (Titusville south to Melbourne). About 40% of the boat fishing took place in the winter season and 20 to 30% in the spring. Recreational fisheries catches for spring, summer and fall of 1963 in the northern area totaled 978,787 pounds of fish. Table 10 presents biomass estimates for species caught in the region including Mosquito Lagoon. A creel census has recently been sponsored by the Merritt Island National Wildlife Refuge for the region but to date is not published.

Anderson and Gehringer (1965) mentioned changes in the region as a response to the missile industry being developed at Cape Canaveral. Commercial fishermen were switching to higher paying jobs related to the space industry and the development pressures were on the rise inspired by additional people moving to the area to work at the missile center.

Gilmore (in press) describes 1950-1970 as the most serious period in the history of the Indian River Lagoon in terms of negative influences by man with dramatic increases in agricultural and urban land use. The high marshes along the southern end of Mosquito Lagoon were accessible to fishes until the 1950's. Over 92% of the mangrove and saltmarsh habitats along the Indian River were impounded for mosquito control, greatly impacting spot, channel bass and striped mullet in the northern portion of the system. Channalization, ditching, filling, pesticide and herbicide applications were common occurrences during what Gilmore aptly labels this period of "great environmental insult" when there was "virtually no concern for water quality".

The central and south end of the Mosquito Lagoon was studied from an ecological stand point beginning in the early 1970's (Mulligan and Snelson 1983, Schooley 1977, Snelson 1980, 1983, Snelson and Bradley 1978, and Snelson et al. 1988). Some of the work that has been done is encouraging as it was specifically intended to provide a baseline, and tracking the condition of populations over the long term was a goal. The baseline provides an inventory of species typically encountered in the past and information as to what habitats within the lagoon are important to certain species (Schooley 1977, Snelson 1980). Some species require the direct use of several habitats in the lagoon during the various phases of their life cycles (Gilmore et al. 1983), thus demanding that proper connections between the habitats and the health of the individual habitats remain intact.

Snelson (1983) provided the first systematic ichthyofaunal survey in the northern section of the Indian River Lagoon through collections made between 1972 and 1980. Collections included numerous stations in Mosquito Lagoon. Sampling occurred

Table 10. Top Five Species Captured by Various Recreational Fishing Methods during Spring, Summer, and Fall 1963 between Ponce de Leon Inlet and Titusville. Species are Listed in order of Biomass (Total Weight in Pounds)

Boat	Bank	Bridge
Sea trout (427,788)	Sea trout (59,079)	Bluefish (45,072)
Sheepshead (34,273)	Puffers (42,261)	Sheepshead (20,240)
Red drum (32,597)	Bluefish (25,605)	Pinfish (15,840)
Black drum (20,758)	Catfish (14,724)	Catfish (12,808)
Pinfish (16,094)	Black drum (10,515)	Spot (8,264)

The nine species above are combined by category below and amount to 785,918 lbs. Sea trout accounted for a very large percentage of the biomass taken that year.

Sea trout	486,867	Sheepshead	54,513
Red drum	32,597	Black drum	31,273
Pinfish	31,934	Puffers	42,261
Catfish	27,532	Bluefish	70,677
Spot	8,264		

throughout the year and predominantly during the daytime. A variety of fishing gear was employed to sample the many habitats in the lagoon. The work yielded an annotated list of fish species and a discussion on the possible reasons for differences in the fauna found in this northern section of the Indian River Lagoon versus that described by Gilmore (1977a) at the southern end.

Species diversity is considerably lower in the northern reaches of the Indian River Lagoon. One important feature noted was the lack of reef-like structure that could be used by fishes in the northern Indian River Lagoon with the exception of the ledges in Mosquito Lagoon. These are found where the ICWW cuts through limestone and coquina in the northern section of Mosquito Lagoon. Snelson (1983) could not adequately sample these ledges but suggested that they might support a number of reef-associated fish that could be missing from the species list. Suggestions for this region being incapable of supporting the larger numbers and varieties of fish seen in the southern Indian River Lagoon were cooler climates (disallowing for more tropical species), only one ocean access (Ponce de Leon Inlet) and the great distance to the Gulfstream (which could transport species into the area).

Schooley (1977) described fish community organization and microhabitat distinctions at 12 stations in the northern Indian River Lagoon which included 2 stations in the Mosquito Lagoon during 1976 and 1977. One of the stations was east northeast of Haulover Canal and about 1/2 mile (.8 km) west of the beach barrier island. The second station was just west northwest of channel marker #26. He described seasonal changes in the community structure and the influence of organic material and depth on community composition. He concluded that nearshore fish communities were richer in summer months in terms of number of specimens, species number and biomass. In summer, there were significant correlations between species and certain environmental parameters. Fall and spring were peak periods for species and biomass diversity. The fall peak was apparently related to the increase in detrital material from the annual seagrass bed "die-back" that attracts detrital feeding benthic invertebrates which in turn draw bottom feeding fishes.

Mulligan and Snelson (1983) provided the first quantitative sampling of epibenthic fish populations in Mosquito Lagoon, north Indian and Banana Rivers. Their objective was to develop a cost-effective database for use as a quantitative baseline for long term monitoring. They determined that using "Importance Values" for fishes gives the best index for assessing change in a long term monitoring program of fish communities. Importance Values involve the use of abundance, frequency of capture and biomass/individual.

They used two fixed stations in the lagoon that represented "typical" open lagoon habitats where monthly sampling was conducted using otter trawls. One of the Mosquito Lagoon stations was unique in several ways including the lack of macroalgae and seagrasses, the large number and consistent presence of ctenophores, and the large production of sciaenid fish (drum). The abundance of drum was correlated to higher salinities which occur in Mosquito Lagoon. Anchoa mitchelli (anchovy) was the numerically dominant species in all areas and all months and the second dominant species for Mosquito Lagoon was typically Bairdiella chrysoura, (silver perch).

The greatest number of species were found in Mosquito Lagoon and Banana River samples leading Mulligan and Snelson to speculate that the high diversities were influenced by the relatively undisturbed conditions of the two areas as compared to Indian River.

Snelson and Bradley (1978) reviewed historical trends in fish mortalities due to cold temperatures in Florida and gave a detailed description of results of the cold spell of 1977 as it affected fish in Mosquito Lagoon and nearby waters. They concluded that, relative to short-term consequences, local fish populations are reduced and that larger fish species and larger individuals are killed by these cold events. The long term effects of cold induced mortalities are probably minimal. Based on their quantitative trawl surveys, Snelson and Bradley (1978) found no differences in total catches before and after the cold period.

Snelson and Williams (1981) gave species accounts of ten elasmobranch species (sharks and rays) they found in the northern Indian River Lagoon including Mosquito Lagoon. The bull shark (Carcharhinus leucas) was the most abundant shark. The bluntnose stingray (Dasyatis sayi) was the most abundant ray and elasmobranch. Sharks and rays apparently were more diverse and numerous in Mosquito Lagoon than in other parts of the northern Indian River Lagoon. Snelson et al. (1989) noted the largest numbers of bluntnose stingrays were consistently found in the Mosquito Lagoon when compared to their other study sites in the northern Indian and Banana Rivers and attributed the distributional differences to the well documented salinity differences in these three areas. Interestingly Snelson et al. (1988) found no such proportions in the abundance of the Atlantic stingray (D. sabina).

In June and July of 1980, about 100 large adult red drum (Sciaenops ocellatus) were found dead or dying in the Indian River near Titusville and Mosquito Lagoon. Cardeilhac et al. (1981) presented data that suggested the mass kill was caused by the fish feeding on blue crabs that were contaminated by metal poisoning (copper, zinc and arsenic). Precise locations of the dead fish were not given and the potential sources of the metals were not noted.

In 1987, Johnson and Funicelli (unpublished) began studying red drum in Mosquito Lagoon and documented for the first time, red drum spawning in an estuary. Their collecting area was concentrated in a 10 km stretch along the ICWW north of Haulover Canal and another was at Ponce de Leon Inlet. The largest number eggs were collected in the lagoon study site and appeared with a new moon. They reported that the ICWW and Haulover Canal may function the way "tidal passes" do by attracting the spawning red drum.

Funicelli et al. (1988) included Mosquito Lagoon in their assessment of the effectiveness of the existing fish sanctuary on the Kennedy Space Center. The sanctuary or "unfished" area was considered to be the northern Banana River and Banana Creek where the public is prohibited due to NASA safety and security requirements. Mosquito Lagoon was sampled along with the Indian River and south Banana River as the "fished" area and then compared to the above unfished area. The sampling program by Funicelli and coworkers provided additional information relative to

fishes and environmental variables but the "treatment" and "nontreatment" areas are so very different in terms of habitat as clearly described in the above reviews that such a comparison may not be valid.

Using trammel nets Funicelli et al. (1988) was able to determine the relative abundance of various species in areas. They also tagged fish of recreational or commercial importance for mark/recapture information. Their data provided interesting comparisons of basic parameters but especially bottom type and vegetation found at the random stations within each water body. The percentage of stations in Mosquito Lagoon sampled having mud bottom and sand bottom types were 51.3% and 70.1%, respectively. Seagrass was encountered in 49.3% of the Mosquito Lagoon stations and algae was observed at 61.8% of the stations. Of the 39 species caught, only 28.2% were common to all of the study's areas. The work also yielded interesting tables of catch per unit effort (CPUE) by species for each area as well as by area by month. Mosquito Lagoon had the next to lowest overall CPUE of all areas at 20.3%.

Associated Database Reference numbers: 5, 15, 29, 36, 43, 44, 45, 47, 50, 51, 52, 53, 55, 56, 57, 59, 60, 62, 63, 64, 65, 66, 67, 81, 82, 100, 101.

#### SEA TURTLES:

All species of these large marine reptiles are classified as threatened or endangered by the U.S. Fish and Wildlife Service under the Endangered Species Act. Due to their protected classification and presence in Mosquito Lagoon they merit special attention. We found that historical trend data specific to Mosquito Lagoon's sea turtles is lacking. One anecdotal statement from Gilmore (in press) stated that fisheries in Mosquito Lagoon were primarily for family use but that 150 green turtles (*Chelonia mydas*) were exported in 1879. With the exception of early fisheries reports (Brice 1897, Wilcox 1897) describing a turtle fishery in the Indian River region taking a heavy toll on green turtles, there are no documented studies of the turtles in Mosquito Lagoon until 1975 (Ehrhart 1983).

The 19th century reports indicate that the green turtle fishery began in about 1878 and was concentrated from the Melbourne area south. Landings data are available but do not give specific capture localities. The data indicate that very large numbers of turtles were landed in the Sebastian to Ft. Pierce sections rather than the Titusville (Mosquito Lagoon) area. Turtling was conducted primarily in winter between November and May using tangle nets. It is clear that the green turtles were severely effected by commercial exploitation over a 17 year period ending in 1895 when captures of turtles dropped dramatically despite considerable fishing efforts (Wilcox 1897). Loggerheads (*Caretta caretta*) were not commercially valuable because their taste was disdained by most, however, they were probably also killed in great numbers through incidental catch.

Ehrhart (1983) found four species of sea turtles in Mosquito Lagoon. The two most common species were the green and the loggerhead but he also found, two Kemp's ridleys (*Lepidochelys kempfi*) and one hawksbill (*Eretmochelys imbricata*). The leatherback (*Dermochelys coriacea*), although also rare, has been reported from the system as well (Witherington and Ehrhart 1989).

Ehrhart's (1983) turtle netting surveys in Mosquito Lagoon yielded capture rates of 0.67 turtles per day (vs. 0.02 captures/day in the northern Indian River). Mosquito Lagoon was the only lagoon in the northern Indian River Lagoon that he could regularly succeed in capturing turtles. However, Witherington and Ehrhart (1989) reported netting turtles near the Sebastian Inlet (approx. 100 km south) and yielding catch per-unit-effort values that are an order of magnitude higher than Mosquito Lagoon. They postulated that frequent cold stunning events in the northern Indian River Lagoon and Mosquito Lagoon might be responsible for fewer green turtles residing in the Mosquito Lagoon (see section on green turtles to follow). The captures in Mosquito Lagoon involved many immature turtles leaving Ehrhart (1983) to conclude that the Chelonia and Caretta populations in the northern Indian River region are composed of juvenile and/or subadult animals.

Mendonca and Ehrhart (1982) described the Mosquito Lagoon as a unique developmental habitat for Chelonia and Caretta with the northern end being less suitable than the southern end where there is little development and extensive seagrass flats. They examined the activity, population size and structure of both greens and loggerheads in Mosquito Lagoon from 1976-1979. Turtles were collected systematically with tangle nets at six stations as well as opportunistically when they were cold stunned and found floating on the surface during the winter of 1977 and 1978. Cold stunning events in the region have been documented many times before, occurring in 1977, 1894, 1978, 1981, 1985, 1986, and 1989. When temperatures have dipped to about 8°C, the turtles become lethargic and can be seen floating at the surface, see Witherington and Ehrhart (1989) for a review.

Netting for loggerheads was most productive during April through October. Turtles apparently were inactive at night. Mendonca and Ehrhart (1982) described trends relative to distribution of the captures for each species within the lagoon. Recapture intervals for both species indicated that there was some degree of residency.

Mosquito Lagoon probably represents the northern limit of the winter range of the green turtle (Witherington and Ehrhart 1989). Mendonca and Ehrhart (1982) hypothesized that green turtles remain in Mosquito Lagoon until they begin to reach reproductive maturity. Although some may leave during colder periods of the year, many stay and may bury in the mud bottom during the coldest periods. The size class distribution of greens immigrating to the lagoon ranged from post-yearling to subadult, in other words did not include the "lost-year" class or adults. They reported a population estimate of 135 green turtles in the lagoon. Witherington and Ehrhart (1989) speculated that the Mosquito Lagoon green turtle "population" was growing based on data collected during the cold stunning events occurring between 1977 and 1986. Mendonca and Ehrhart's netting studies indicate that greens were caught with the greatest frequency in August.

Mendonca (1983) noted that green turtles in Mosquito Lagoon roam much larger distances (average of 8.2 km/day) and in unpredictable patterns in fall and winter when the water temperatures drop below 19°C as compared to warmer periods of the year (average travel of 2.6 km/day). This unpredictable winter travel was postulated to be attempts to leave the lagoon. The lagoon was referred to as a "funnel trap"

whereby animals have difficulty finding their way out via the only two exits at Haulover Canal or Ponce de Leon Inlet. This would agree with Witherington and Ehrhart (1989) as they discussed the cold stunned turtles being "trapped" in the lagoon and then succumbing to the cold temperatures. (Note similar suggestions relative to fish stunning events in the Fish section above.) Another hypothesis for the unpredictable travel patterns is that the increased travel activity might be an effort to produce metabolic heat.

Mendonca (1983) found Mosquito Lagoon green turtles in deeper sloughs during periods of low water temperatures where they probably did not feed since seagrasses are not found in these areas. In summer they were much more predictable and spent about 70% of the day on the seagrass flats; when water temperatures rose above 31°C they moved back to the deeper, cooler waters. Their activities are curtailed at night when they "sleep" and they are often found very close to the same sleeping site each night.

Syringodium filiforme and Halodule wrightii were the dominant species of vegetation found consumed by green turtles in Mosquito Lagoon (Mendonca 1983). Syringodium was found to be twice as abundant as Halodule in the green turtles examined.

The loggerhead population in Mosquito Lagoon appears to be made up of juveniles, the majority ranging between 50 and 80 cm straight line carapace length, none of the very small sizes were seen which contrasts with findings for greens. The loggerheads surveyed grew faster and matured earlier than greens. Although loggerheads exhibit some degree of residency in the lagoon they do appear to migrate to and from the lagoon. Mendonca and Ehrhart (1982) reported a population estimate of 253 loggerheads. They stated that the estimate was probably low based on field observations and interviews with fishermen.

Associated Database Reference numbers: 3, 15, 42, 71, 72, 98, 102, 117, 118, 120, 121.

#### WADING BIRDS:

Wading birds play an important role in aquatic systems (i.e., energy transfer). The birds affect the fish, invertebrates, reptiles, and submerged aquatic vegetation by their various feeding strategies. Trost (unpublished) evaluated wading bird usage and vegetation changes of salt marshes, including two in Mosquito Lagoon, before and after impoundment for mosquito control. Two sites studied in the lagoon were Pardon Island and a marsh in southwest Mosquito Lagoon. As in all the other study sites, he documented a substantial increase in the density of birds using these two marshes after impoundment.

Data from surveys of wading birds on Kennedy Space Center (Smith and Breininger, unpublished) are available for the years 1987 through 1990 and include three stations in Mosquito Lagoon, two classified as impoundments and one as open estuary. Surveys were conducted once each month by two observers utilizing a helicopter. Approximately 43 surveys over the four year period yielded sightings of 23 bird species

at the Mosquito Lagoon stations (Table 11). Frequency of occurrence and relative density of each species are listed in the Table as well. One species, the woodstork (Mycteria americana), is federally listed as endangered and five are listed by the State of Florida as species of special concern. Bird Island, in northern Mosquito Lagoon was, until 1982, the site of significant nesting for woodstorks. The island was abandoned as a nesting site after the vegetation was damaged by the freeze in the winter of 1981.

Associated Database Reference numbers: 103, 114, 115.

#### MARINE MAMMALS:

Literature searches thus far reveal very few sources of marine mammal data for the study area. The Marine Mammal Stranding and Salvage Network (MMSSN), coordinated by the National Marine Fisheries Service, has a database for records (1977 to the present) of stranded (dead) or unique sightings of marine mammals within U.S. waters. It does not include data regarding the West Indian manatee. Table 12 lists the eight species reported within the Canaveral National Seashore and a breakdown of those that were reported to be found in the Mosquito Lagoon itself. The distribution of these strandings is plotted in Figure 28.

The bottlenose dolphin (Tursiops truncatus) is by far the most commonly sighted marine mammal in the lagoon followed by the manatee. A bottlenose dolphin home-range study (Provancha et al. 1982, Odell and Asper 1990) involved surveys that included Mosquito Lagoon. Several of the dolphins marked in the Cocoa and Titusville area for that study were often sited in Mosquito Lagoon. The general conclusion from the study was that most of the dolphins were year round residents of the lagoonal complex and thus this "estuarine population" could be effected by various perturbations in the system.

Hersh et al. (1990) studied mortality patterns of bottlenose dolphins over an eight year period in the Indian/Banana River system including Mosquito Lagoon. The data for the entire region were pooled for the analysis, hence, trends specific to Mosquito Lagoon are not available.

Manatees (Trichechus manatus) are seen in the lagoon and use it as a travel corridor to other sections of their east coast habitats, at least since the Haulover Canal was built in 1854. However, aerial surveys over sections of the lagoon (Shane 1983 and B. Bonde, pers. comm.) indicate that, despite it's relatively undisturbed condition, the lagoon is not an area with particularly high numbers of manatees. Shane commented that the counts of manatees in Mosquito Lagoon and northern Indian River were extremely low and contrasted sharply with those from Banana River and Indian Rivers. Her surveys indicated that manatees in Mosquito Lagoon were typically seen in the ICWW or along the spoil islands near the ICWW. She speculated that manatees don't use the lagoon to much extent because of the lack of freshwater sources and dredged areas. Dredged areas or basins are often used by manatees in other areas, especially in the Banana River (Provancha and Provancha 1988).

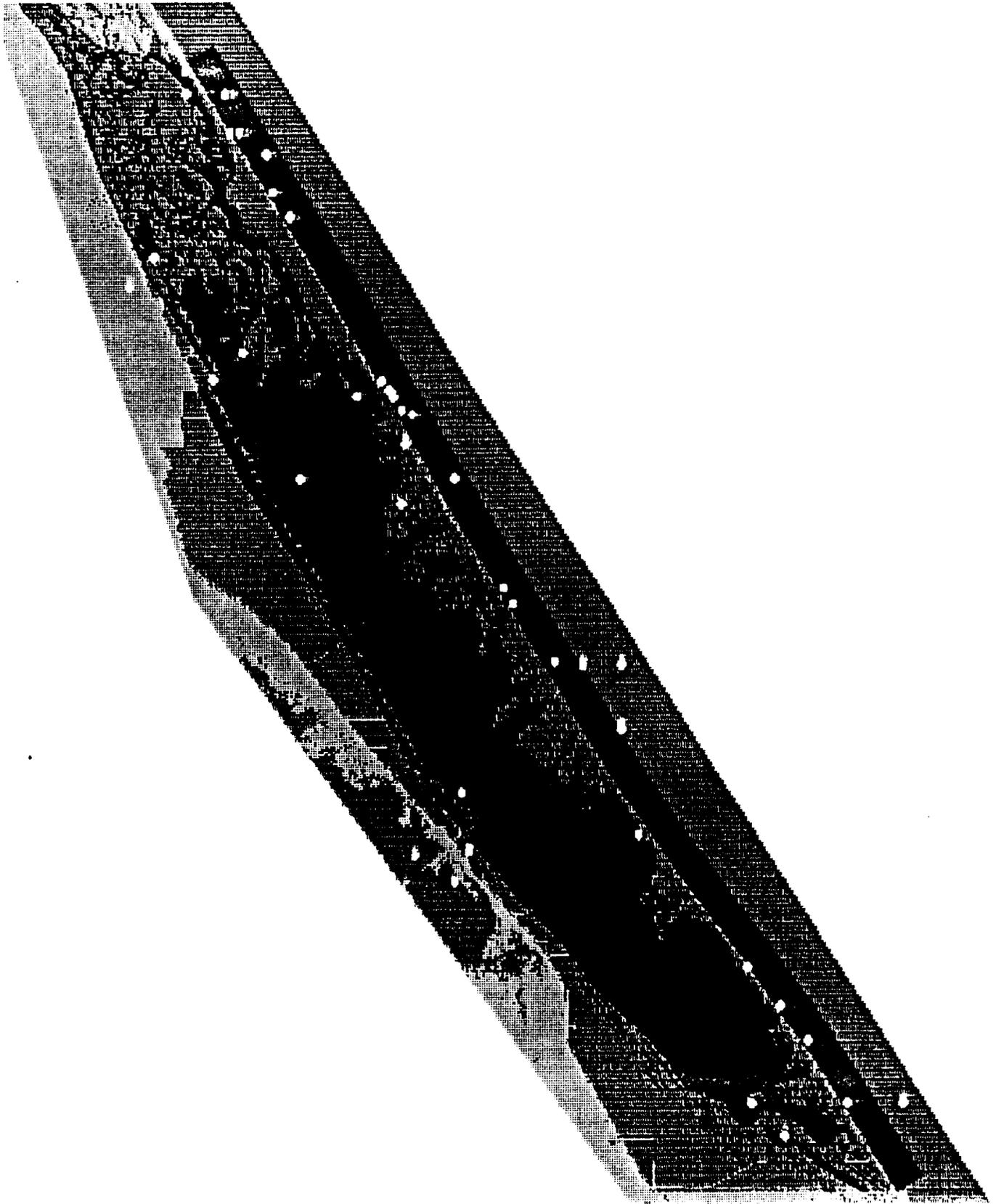


Figure 28. Locations of Marine Mammal Strandings, Represented by White Circles, in the Vicinity of Mosquito Lagoon from 1977 to 1990 (scale = 1:160,000).

Table 11. Species of Birds Observed during Monthly Wading Bird Surveys over Mosquito Lagoon.

Bird Species (Common Name)	Status*	Number of Siting Events (A)	Total Number of Individuals (B)	Relative Density (B/A)
Black-crowned Night-heron		4	15	3.75
Blue-winged Teal		28	2502	89.3
Cattle Egret		6	26	4.3
Common Merganser		1	2	2
Coot		8	1136	142
Great Blue Heron		184	407	2.2
Glossy Ibis		90	2297	25.5
Great Egret		284	2422	8.52
Green-winged Teal		1	4	4
Little Blue Heron	SSC	68	310	4.55
Lesser Scaup		5	80	16
Mottled Duck		18	310	17.2
Northern Shoveler		8	247	30.8
Northern Pintail		8	1072	134
Red-breasted Merganser		5	17	3.4
Reddish Egret	SSC	28	35	1.25
Roseate Spoonbill	SSC	32	160	5
Snowy Egret	SSC	170	5932	34.8
Tricolored Heron	SSC	159	1432	9.0
White Ibis		176	11848	67.3
Wigeon		32	8548	267.1
Wood Stork	E	26	95	3.6
Yellow-crowned Night-heron		1	1	1

\* Federally Threatened (T), or Endangered (E); State Listed Species of Special Concern (SSC)

Table 12. Listing of Stranded Marine Mammal Species Recorded for the Canaveral National Seashore and Mosquito Lagoon between 1977 and 1990.

Marine Mammal Species/Common Name	All Strandings	Reported Inside Lagoon (only)
<i>Kogia breviceps</i> /Pygmy Sperm Whale	7	1
<i>Tursiops truncatus</i> /Atlantic Bottlenose Dolphin	50	12
<i>Stenella frontalis</i> /Spotted Dolphin	1	0
<i>Phocoena phocoena</i> /Harbor Porpoise	1	1
<i>Physeter catodon</i> /Sperm Whale	1	0
<i>Mesoplodon minus</i> */True's Beaked Whale	1	0
<i>Kogia simus</i> /Dwarf Sperm Whale	1	0
<i>Tursiops sp.</i> /Dolphin sp.	2	0
<i>Feresa attenuata</i> /Pygmy Killer Whale	1	0
Total	65	14

\* Identification incomplete

It should be noted that no intensive studies of manatees using Mosquito Lagoon have been undertaken. Based on our experiences in the lagoon and work in the Banana River, one would expect to see animals using both the east and west sections of the northern end of the Canaveral National Seashore due to freshwater sources, channelizations and the availability of some seagrasses. These two areas are attractive due to the features mentioned but are also areas that are potentially dangerous to manatees due to the concentration of boat traffic with limited space to avoid boats. Today the authors and rangers working the park note that manatees are generally seen along the intercoastal and in the northeastern corner of the lagoon near Eldora and Turtle Mound.

Florida's Department of Natural Resources is currently involved in developing a manatee protection plan for Volusia County (Jim Valade, FLDNR, Pers. comm.). They have just begun biweekly aerial surveys over the Volusia County section of the lagoon and so new information will become available. We will attempt to collate the information for Mosquito Lagoon relative to the FLDNR mortality database for manatees as well.

Associated Database Reference numbers: 42, 79, 80, 89, 90, 125, 126, 127.

## INVERTEBRATES

Several invertebrate studies have been conducted in Mosquito Lagoon, all between 1971 and 1978. The studies involved only one or two stations near Haulover Canal, which is the dredged channel that connects the Indian River with Mosquito Lagoon. Three of the invertebrate studies were associated with seagrass. Hall and Eiseman (1981) reported low species diversity of seagrass epiphytes at the Haulover site and this was thought to be due to the sparse population of Halodule wrightii caused by the 1977 freeze, the large amount of fine silt and fluctuations in temperature and salinity. Water temperatures ranged from 11-34°C and salinity from 20-46‰.

Nelson et al. (1982) noted that environmental variability was greater at their Haulover site compared to the southern stations (Sebastian, Link Port and St. Lucie). He also noted greater amphipod abundance at Haulover Canal. The mean abundance at the two northern stations (Haulover and Banana River) was twice that of the three southern stations combined. The greater abundance was believed to be due to predation pressure rather than environmental variability. Amphipod distributional patterns were thought to be related to the relative proximity of ocean inlets.

Young et al. (1976) set up cages in seagrass beds at Haulover Canal, Link Port and St. Lucie to document predator/prey relationships of macrobenthos. Thirty-three species (mainly polychaetes) were found at the Haulover site. Thirty-two showed increases in density within the cages. It was expected that an overall increase in density of macrofauna from caged versus uncaged samples would be observed. This was the case at the Haulover site but not at the two southern sites where caging resulted in an unexplained decrease in density. There were lower total numbers of individuals and diversity of decapod crustaceans inside cages at Haulover than at the southern-most station. Although presumably important in regulating densities of

certain prey species at all the sites, decapods have a lesser overall impact on macrobenthos at Haulover than stations further south. The decrease in caging effect from north to south may be explained in terms of increased predation inside cages by decapods.

Buzas and Severin (1982) showed that Haulover Canal and stations at inlets like St. Lucie were distinct from other stations in their foraminifera study. Twenty-one species, two exhibiting peak densities, were found at Haulover. The overall density and number of species of foraminifera clearly increased in a southerly direction. A gradient of increasing environmental variability towards the north end of the Indian River Lagoon was evident. This increasing gradient is positively correlated with the decrease in foraminifera densities in the northern area. Grizzle's (1974) decapod study encompassed all estuarine water bodies in Brevard County and included Mosquito Lagoon. He documented the presence of eight species of decapods at two locations in the southern portion of Mosquito Lagoon.

Associated Database Reference numbers: 15, 16, 18, 20, 22, 23, 24, 25, 27, 30, 31, 32, 33, 49, 56, 57, 68, 70, 76, 78, 85, 123.

## SHELLFISH

Two groups of invertebrates, crustaceans and mollusks, contribute to the shellfish fisheries of the region. Exploited invertebrates include oysters, clams, blue crabs, and penaeid shrimp. Florida Department of Natural Resources Shellfish Environmental Assessment Section is the primary source of shellfish related studies in Mosquito Lagoon and the surrounding area. The lagoon is split into two sections for shellfish management. The first contains the waters south of the Volusia/Brevard County line and includes the northern part of the Indian River from Turnbull Creek south to the Florida East Coast Railway (Harp et al. 1985). The second area is north of the Volusia/Brevard County line up to the ICWW channel marker #61 and all the area from east to west (Poole and Harp 1985, Royal and Pierce 1990). These areas were surveyed as sites for potential shellfish harvesting in the 1960's and were classified as prohibited, approved, or conditionally approved. The area in Brevard County was classified as approved for shellfish harvesting. In the late 1970's and early 1980's it was resurveyed in order to determine if the classification was still appropriate. It was determined that the classification of approved would remain in place. No trends were noted between fecal coliform densities and natural physico-chemical parameters in the Mosquito Lagoon portion and so no restrictions were applied (Harp et al. 1985). The northern part of the lagoon (Volusia County) was also resurveyed and the classification was changed from approved to conditionally approved. The classification was changed due to the strong correlation between fecal coliform levels and three day rainfall. Poole and Harp (1985) and Royal and Pierce (1990) recommended the following: "When rainfall of 1.50 inches (3.81 cm) or greater is measured within a 72 hour period at the Edgewater Wastewater Treatment Plant, and/or when catastrophic events such as hurricanes, sewage spills or detection of Ptychodiscus brevis (a toxic dinoflagellate that causes red tide) occurs, the areas will be closed to harvesting of shellfish. The area will reopen when sufficient time has elapsed for depuration to occur and when all other parameters are shown to be

within Interstate Shellfish Sanitation Program standards." The northern lagoon also has two prohibited areas which are: the waters along the ICWW from channel marker #71 southward to channel marker #15, and the water from Grouper Avenue south to Turtle Mound (Poole and Harp 1985, Royal and Pierce 1990).

In addition to the above mentioned classification surveys, Grizzle (1988,1990) studied the distribution and abundance of two shellfish species, Crassostrea virginica (eastern oyster) and Mercenaria mercenaria (hard clam) and environmental factors effecting them. The study took place in the northern part of Mosquito Lagoon, within the borders of Canaveral National Seashore. Halodule wrightii was the dominant seagrass found. The amount of bottom area covered by oyster reefs decreased in Mosquito Lagoon from north to south as did tidal ranges. Annual water temperatures ranged from 12.3-32.6°C while salinities ranged from 30.7-31.3%. Oyster reefs were primarily found in waters greater than 1 m deep where tidal currents are presumed to be the greatest. Clams were only found in the vicinity of waters greater than 1 m deep. Sediment types ranged from mixtures of soft sand/mud to firm sand/shell. Clams were found in the highest abundance in firm sand/shell sediments. There was no north-south trend with clams and there was no correlation between their abundance and tidal range.

In Mosquito Lagoon and other areas of northeast Florida blue crabs (Callinectes sapidus) support a large commercial and recreational fishery (Steel, 1979). Blue crabs spend their entire life in the estuary except during the female spawning migrations. Spawning may occur during all but the coldest months or whenever water temperatures exceed 22°C (Tagtz, 1968). Mating is thought to occur primarily in brackish waters, then females migrate to high salinity areas near tidal passes to spawn. Male blue crabs tend to remain in the lower salinity areas year-round. Blue crab larvae mature primarily offshore where they pass through seven zoeal stages, then molt to a megalops stage as they begin the journey back into the estuary. Small crabs occupy shallow water habitats and gradually move to deeper water as they increase in size. Commercial landings on the east coast historically averaged about 7 million pounds but have declined during the last 10 to 20 years according to Steele (1979). Peak landings occur summer through fall with all catches coming from estuarine waters.

Three species of penaeid shrimp, Penaeus setiferus (whites), Penaeus aztecus (browns), and Penaeus duorarum (pinks), contribute to the east coast Florida landings. All three species spawn offshore where their eggs and larvae develop as they drift toward the estuary. Juveniles reside for several months in the estuary where seagrasses provide the primary habitat (Durako et al. 1988). Brown shrimp have a peak inshore recruitment in February and March. White shrimp recruitment occurs in May and June. Pink shrimp form only a small part of the commercial catch in northeast Florida but they contribute significantly to a live-bait fishery extending south from Ponce de Leon Inlet. Pink shrimp spawn year round with a peak in early spring (Durako et al. 1988). The vast majority of commercial catch is taken from offshore waters but the bait shrimp fishery is supported primarily by lagoon catches using push nets, dip nets and cast nets.

Associated Database Reference numbers: 5, 67, 88, 93, 94, 95, 96, 104, 108.

## MOSQUITO CONTROL

Mosquito Lagoon lies within two mosquito control districts, Brevard and Volusia, and is managed differently within each. These two agencies are responsible for most of the mosquito control studies that have occurred in the lagoon. Saltmarsh, mosquito control and impoundment studies have been conducted (Montague et al. 1984, Trost, unpublished) in small sections of the Mosquito Lagoon.

The Brevard County Mosquito Control District (BCMCD) was incorporated in 1937 and spraying to control mosquito populations was begun at that time. In the late 1950's BCMCD, in conjunction with various other agencies, implemented construction of mosquito control impoundments (Jim Hunt pers. comm.). These impoundments were constructed up until 1972. At the present time only maintenance measures are performed on these existing impoundments.

Through the years various pesticides, larvicides and other chemicals have been used in the attempt to control mosquito populations. As early as 1937 diesel was used, although in 1988 this was replaced by a chemical called Golden Bear which is a refined diesel oil that is used in considerably lower amounts. In the early 1950's the pesticide DDT was used and in the mid 1960's Paris green, although neither of these were sprayed in the lagoon area. The main chemical used in Mosquito Lagoon since 1968 is the larvicide, Altosand. The southwestern area of Mosquito Lagoon from state road 406 south is a frequently sprayed area. The rest of the lagoon that is managed by Brevard County is rarely sprayed.

Volusia County Mosquito Control District (VCMCD) was also incorporated in 1937 when two smaller districts merged. In the 1920's and 1930's hand ditching began in the lagoon and was later replaced (1940's and 1950's) by draglines. Impoundments became popular in the 1960's and 1970's, although by the mid 1980's they were no longer in use in the lagoon (they were opened up). With the 1980's came rotary ditching, which is still in use now. The purpose of rotary ditching was for source reduction. Areas where mosquitoes were able to breed, like potholes, were connected to permanent sources of water. Not only did the water flood the moist ground that was needed for egg laying but it allowed access for fish whose primary food source was mosquito larvae. In addition to these methods, insecticides were used that affected the individual stages of the mosquito lifecycle. Since 1978, the larvicide Altosid has been the primary chemical sprayed in the lagoon by VCMCD. Unlike BCMCD, Volusia County frequently sprays in the areas of Mosquito Lagoon that they manage.

Associated Database Reference numbers: 46, 114, 130, 132, 134, 135, 137, 138, 153, 157.

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## Appendix B

### I. Biological Data

<u>Dates</u>	<u>Parameters</u>	<u>Agency</u>
1977-1987	Marine Mammal Stranding Records	Smithsonian Institute
1974-1976	Marine Mammal Stranding Records	Sea World, Inc
1987-1990	KSC Wading Bird Surveys	Bionetics/NASA
1979-1990	Shellfish Surveys Coliform/basic physical	Florida DNR
1971-1986	Shellfish Surveys Coliform/basic physical	Brevard County Department of Natural Resources
1983-1990	Seagrass Transects	Bionetics/NASA
1988-1990	Mosquito Larvae and Control	Volusia County Mosquito Control
1985-1990	Mosquito Larvae and Control	Brevard County Mosquito Control

### II. Physical/Chemical Data

1984-1990	Surface Waters: Metals pH, basic physical	Bionetics/NASA
1986-1987	Groundwater	EG&G/NASA
1990	Well and Springs	St. Johns River Water Management District
1981-1990	Surface Waters: basic physical, nutrients	Brevard County Dept of Natural Resources

## Appendix B (continued)

1970-1989	Surface Waters,Storet: basic physical, pH coliform, biological diversity, flow, water quality indices, rankings	Florida DER
1985-1990	Surface Waters/Shell -fish: Fecal coliform, basic physical	Florida DNR
1989-1990	Surface Waters:basic physical, nutrients coliform	Volusia County Division of Natural Resources
1970-1990	STORET Water Quality Data	Environmental Protection Agency/Florida DER
1984-1988	Surface Water: lagoon and impoundments, basic physical and water level	Merritt Island National Wildlife Refuge, US Fish and Wildlife Service

## Appendix C

### List of Individuals Contacted for Phase I.

John Stiner/Canaveral National Seashore, NPS, Titusville, FL.

Derek Busby/National Estuaries Program, EPA, Melbourne, FL.

Bob Day/National Estuaries Program, EPA, Melbourne, FL.

Conrad White/Dept. of Natural Resources, Brevard County, Merritt Island, FL.

Karen Durhing/Division of Natural Resources, Volusia County, Deland, FL.

Mark Freidemann/Division of Surface Waters, Florida DER, Tallahassee, FL.

Liz Ulmer/Bureau of Information, Florida DER, Tallahassee, FL.

Brian Pierce/Shellfish Environmental Assessment Section, Florida DNR, Titusville, FL.

Daniel Odell/Southeastern Marine Mammal Stranding Network, Sea World Research Institute, Orlando, FL.

Paul Haydt/Volusia County Mosquito Control, Ormond Beach, FL.

Mr. Gamble/Volusia County Mosquito Control, New Smyrna, FL.

Jim Hunt/Brevard County Mosquito Control, Titusville, FL.

Bill Sargeant/Environmental Sciences, St. Johns River Water Management District, Palatka, FL.

Dr. Franklin Snelson/University of Central Florida, Orlando, FL.

Diane Barile/Marine Resource Council, Melbourne, FL.

Fred Morris/St. Johns River Water Management District, Palatka, FL.

Brian Poole/Aquatic Preserves/ Florida DNR, Melbourne, FL.

Dwight Cooley/Merritt Island National Wildlife Refuge, USFWS, Merritt Island, FL.

Ken Haddad/Florida Marine Research Institute, Florida DNR, St. Petersburg, FL.

Randy Sleister/Division of Natural Resources, Volusia County, Deland, FL.

Christin Metzger/Harbor Branch Oceanographic Institute, Library, Ft. Pierce, FL.

## Appendix C (continued)

Dr. Grant Gilmore/Harbor Branch Oceanographic Institute, Ft. Pierce, FL.

Christal Wood/National Aeronautics and Space Administration, Kennedy Space Center, FL.

Dr. John Morris/Florida Institute of Technology, Melbourne, FL.

Dr. Nicholas Funicelli/University of Florida, National Fisheries Laboratory, Gainesville, FL.

Dr. Doug Morrison/USFWS, National Fisheries Laboratory, Gainesville, FL.

Mark Mercadante/Johnson Controls, Cape Canaveral Air Force Station, FL.

Dr. Robert Virnstein/Environmental Sciences, St. Johns River Water Management District, Palatka, FL.

John Dennard/Technical Data Services, St. Johns River Water Management District, Palatka, FL.

Micheal Holmes/Planning, Volusia County, Deland, FL.

Dr. Kevin Erwin/Kevin Erwin Ecologist Consulting, Inc., Ft Myers, FL.

Gary Goode/Mosquito Control, Volusia County, Daytona, FL.

Rick Mann/Mosquito Control, Volusia County, New Smyrna, FL.

Joel Steward/Environmental Sciences/ St. Johns River Water Management District, Palatka, FL.

## Appendix D

### 1.) Low altitude photography:

<u>Years</u>	<u>Type</u> <sup>1</sup>	<u>Scale</u>
1989	CIR	1"=1000'
1986	CIR	1"=1000'
1984	CIR	1"=1000'
1983	CIR	1"=1000'
1982	CIR	1"=1000'
1969	B/W	1"=50000'
1958	B/W	1"=20000'
1951	B/W	1"=20000'
1943	B/W	1"=20000'

### 2.) U2 Imagery

<u>Years</u>	<u>Type</u>
1983	CIR*
1989	CIR
1990	CIR, DLG, Color, and B/W expected from NPS RemoteSensing and GIS Program.

### 3.) Landsat Scenes

<u>Years</u>	<u>Type</u>
1987	TM
1989	TM

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<sup>1</sup> CIR = Color Infra Red; B/W = Black and White; TM = Thematic Mapper

\* Housed at the Ground Engineering Office at KSC

## Appendix E

FDER Water Quality Classifications and Standards  
(from Edward E. Clark Engineers and Scientists, in press)

PARAMETER	FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
	GROUND WATER		CLASS III				
	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	RECREATION FISH & WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL	
Aldrin-Dieldrin		0.003 ug/l	0.003 ug/l	0.003 ug/l			
Alkalinity		20 mg/l min. as as CaCO		20 mg/l min. as CaCO (fresh)	600 mg/l max. as CaCO		
Aluminum			1.5 mg/l	1.5 mg/l (marine) 0.02 mg/l (fresh)			
Ammonia, un-ionized		0.02 mg/l					
Antimony			0.2 mg/l	0.2 mg/l (marine)			
Arsenic	0.05 mg/l (P)	0.05 mg/l	0.05 mg/l	0.05 mg/l	0.05 mg/l	0.05 mg/l	
Bacteriological Quality	Total Coliform 4/100 ml (P)	1,000/100ml mean; 200/100ml mean fecal	70/100 ml median; 14/100 ml median fecal	1,000/100ml mean; 200/100 ml mean fecal			
Barium	1 mg/l (P)	1 mg/l					
Benzene	1 ug/l (P)						
Beryllium		0.011 mg/l soft 1.10 mg/l hard		0.011 mg/l soft 1.10 mg/l hard (fresh)	0.1 mg/l soft 0.5 mg/l hard		
Biological Integrity		min. 75% of Diversity Index	min. 75% of Diversity Index	min. 75% of Diversity Index			

PARAMETER	FDER					
	GROUND WATER		SURFACE WATER QUALITY CLASSIFICATIONS			
	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH & WILDLIFE	CLASS IV AGRICULTURAL	
					CLASS V INDUSTRIAL	
Boron						0.75 mg/l
Bromine & Bromates		0.1 mg/l free bromine, 100 mg/l bromates	0.1 mg/l free bromine, 100 mg/l bromates	0.1 mg/l free bromine, 100 mg/l bromates (marine)		
Cadmium	0.010 mg/l (P)	0.0008 mg/l soft 0.0012 mg/l hard	0.005 mg/l	0.0008 mg/l soft (fresh) 0.0012 mg/l hard (fresh) 0.005 mg/l (marine)		
Carbon Tetra-chloride	3 ug/l (P)					
Chlordane		0.01 ug/l	0.004 ug/l	0.01 ug/l (fresh) 0.004 ug/l (marine)		
Chlorides	250 mg/l (S)	250 mg/l	10% above background	10% above background (marine)		10% above background (marine)
Chlorine, Residual		0.01 mg/l	0.01 mg/l	0.01 mg/l		
Chromium	0.05 mg/l (P)	0.05 mg/l total	0.05 mg/l total	0.05 mg/l total	0.5 mg/l total	0.5 mg/l total
Color	15 color units (S)	no nuisance conditions	no nuisance conditions	no nuisance conditions	suitable for use	no nuisance conditions

PARAMETER	FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
	GROUND WATER	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	RECREATION CLASS III FISH & WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Copper	1 mg/l (S)		0.03 mg/l	0.015 mg/l	0.03 mg/l (fresh) 0.015mg/l (marine)	0.05 mg/l	0.05 mg/l
Corrosivity		Noncorrosive (S)					
Cyanide			0.005 mg/l	0.005 mg/l	0.005 mg/l	0.005 mg/l	0.005 mg/l
2,4 - D			100 ug/l (P)				
DDT			0.001 ug/l	0.001 ug/l	0.001 ug/l		
Demeton			0.1 ug/l	0.1 ug/l	0.01 ug/l		
1,2-Dichloro-ethane	3 ug/l (P)						
Detergents			0.5 mg/l	0.5 ug/l	0.5 ug/l	0.5 ug/l	0.5 ug/l
Dissolved Solids			500 mg/l (S)				
			(total)				
			500 mg/l mo. avg.				
			1,000 mg/l max.				
Endosulfan			0.003 ug/l	0.001 ug/l	0.003 ug/l (fresh) 0.001 ug/l (marine)		
Endrin	0.2 ug/l (P)		0.004 ug/l	0.004 ug/l	0.004 ug/l		
Ethylene Dibromide	0.02 ug/l (P)						
Fluorides	1.4-2.4 mg/l		1.5 mg/l	1.5 mg/l	5.0 mg/l (marine) 10.0 mg/l as fluoride ion	10.0 mg/l as fluoride ion	10.0 mg/l as fluoride ion

PARAMETER	FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
	GROUND WATER		FDER				
	POTABLE WATER STANDARDS	0.5 mg/l (S)	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH & WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Foaming Agents							
Guthion		0.01 ug/l	0.01 ug/l	0.01 ug/l	1.0 mg/l (fresh) 0.3 mg/l (marine)	1.0 ug/l	
Heptachlor		0.001 ug/l	0.001 ug/l	0.001 ug/l			
Iron	0.3 mg/l (S)	0.3 mg/l	0.3 mg/l				
Lead	0.05 mg/l (P)	0.03 mg/l	0.05 mg/l				
Lindane	4 ug/l (P)	0.01 ug/l	0.004 ug/l				0.05 mg/l
Malathion		0.1 ug/l	0.1 ug/l				
Manganese	0.05 mg/l (S)		0.1 mg/l				
Mercury	0.002 mg/l (P)	0.0002 mg/l	0.0001 mg/l				0.0002 mg/l
Methoxy-Chlor	100 ug/l (P)	0.03 ug/l	0.03 ug/l				0.0002 mg/l
Mirex		0.001 ug/l	0.001 ug/l				
Nickel		0.1 mg/l	0.1 mg/l				0.1 mg/l
Nitrates (as N)	10 mg/l (P)	10 mg/l					
Nitrogen Total (as N)							

See 17-3.011(11)

FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
GROUND WATER		CLASS II	CLASS III	CLASS IV	CLASS V	
PARAMETER	POTABLE WATER STANDARDS	SHELLFISH	FISH & WILDLIFE	AGRICULTURAL	INDUSTRIAL	
Nutrients		varies	varies	discharge limited	discharge limited	
Odor	threshold odor number 3 (S)	no nuisance conditions	no nuisance conditions	suitable for use	suitable for use	
Oils & Grease	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	5.0 mg/l; no taste or odor	
Parathion	0.04 ug/l	0.04 ug/l	0.04 ug/l			
pH	6.5 minimum (S)	1.0 unit variation	1 unit variation	1 unit variation	1 unit variation	
		6.9 - 8.5	6.5 - 8.5	6.0-8.5 (fresh)	6.0 - 8.5	
				6.5-8.5 (marine)	5.0 - 9.5	
Phenolic Compounds	0.001 mg/l	0.001 mg/l	0.001 mg/l	0.001 mg/l	0.001 mg/l	
Phosphorus, Elemental		0.0001 mg/l	0.0001 mg/l	0.0001 mg/l		
Phosphorus, Total (as P)			See 17-3.011(11)			
Phthalate Esters		0.003 mg/l	0.003 mg/l (fresh)			
PCBs		0.001 ug/l	0.001 ug/l	0.001 ug/l		
Radioactive Substances	Ra: 5 pCi/l (P) a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	Ra: 5 pCi/l a: 15 pCi/l	
Selenium	0.01 mg/l	0.025 mg/l	0.025 mg/l			

PARAMETER	FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
	GROUND WATER	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH & WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Silver	0.05 mg/l	0.00007 mg/l	0.00007 mg/l	0.000005 mg/l	0.00007 mg/l (fresh) 0.00005 mg/l (marine)		
Sodium	160 mg/l						
Specific Conductance		varies	varies	varies	varies	varies	varies
Sulfates	250 mg/l (S)						
Suspended Solids							
2,4,5 - TP	10 ug/l (P)	10 ug/l					
Temperature		no nuisance conditions	no nuisance conditions	no nuisance conditions	no nuisance conditions	no nuisance conditions	no nuisance conditions
Tetrachloroethylene	3 ug/l (P)						
Total Dissolved Gases		110 % of saturation value	110 % of saturation value	110 % of saturation value	110 % of saturation value		
Toxaphene	5 ug/l (P)	0.005 ug/l	0.005 ug/l	0.005 ug/l	0.005 ug/l		
Transparency		min. 90% of background	min. 90% of background	min. 90% of background	min. 90% of background		
1,1,1-Trichloroethane	200 ug/l (P)						

PARAMETER	FDER		SURFACE WATER QUALITY CLASSIFICATIONS				
	GROUND WATER	POTABLE WATER STANDARDS	CLASS I POTABLE	CLASS II SHELLFISH	CLASS III RECREATION FISH & WILDLIFE	CLASS IV AGRICULTURAL	CLASS V INDUSTRIAL
Trichloro-ethylene		3 ug/l (P)					
Trihalomethanes		0.10 mg/l (P)					
Turbidity		1 NTU month av. 5 NTU 2-day av. (P)	29 NTU above background	29 NTU above background	29 NTU above background	29 NTU above background	29 NTU above background
Vinyl Chloride		1 ug/l (P)					
Zinc		5 mg/l (S)	0.03 mg/l	1.0 mg/l	0.03 mg/l (fresh)	1.0 mg/l	1.0 mg/l

[1] Actual standards are more complex than numbers displayed in chart (see Chapter 17-3, F.A.C.)  
 [2] These values are based on 6,000 samples from 94 lake, stream and estuary sampling stations collected from 1974-1982 by FDER. The first value is the tenth percentile, the second value is the median, and the last value is the ninetieth percentile.  
 (P) Primary Drinking Water Standard  
 (S) Secondary Drinking Water Standard

Source: Reference 30

## Appendix F

### Annotated List of Fish Species from the Northern Part of the Indian River Lagoon System

FAMILY CARCHARHINIDAE – requiem sharks

1. *Carcharhinus leucas* (bull shark).  
Mesohaline; open lagoon; frequent (Snelson and Williams, 1981).
2. *Carcharhinus limbatus* (blacktip shark).  
Mesohaline; open lagoon; abundance unknown but probably occasional and seasonal (Snelson and Williams, 1981).
3. *Carcharhinus plumbeus* (sandbar shark).  
Mesohaline; open lagoon; rare (Snelson and Williams, 1981).
4. *Negaprion brevirostris* (lemon shark).  
Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY SPHYRINIDAE – hammerhead sharks

5. *Sphyrna lewini* (scalloped hammerhead).  
Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY PRISTIDAE – sawfishes

6. *Pristis pectinata* (smalltooth sawfish).  
Once frequent in the lagoons but no recent records (Snelson and Williams, 1981).

FAMILY DASYATIDAE – stingrays

7. *Dasyatis americana* (southern stingray).  
Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).
8. *Dasyatis sabina* (Atlantic stingray).  
Mesohaline; open lagoon, lagoon perimeter; common (Snelson and Williams, 1981).
9. *Dasyatis sayi* (bluntnose stingray).  
Mesohaline; open lagoon, lagoon perimeter; common (Snelson and Williams, 1981).
10. *Gymnura micrura* (smooth butterfly ray).  
Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY MYLIOBATIDAE – eagle rays

11. *Aetobatus narinari* (spotted eagle ray).  
Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).
12. *Rhinoptera bonasus* (cownose ray).  
Mesohaline; open lagoon; frequent but seasonal (Snelson and Williams, 1981).

FAMILY LEPISOSTEIDAE – gars

13. *Leptosteus platyrhincus* (Florida gar).  
Fresh, oligohaline; ditches, ponds, impoundments; frequent.

FAMILY AMIIDAE – bowfins

14. *Amla calva* (bowfin).  
Fresh; ponds; occasional.

FAMILY ELOPIDAE – tarpons

15. *Elops saurus* (ladyfish).  
Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; frequent.
16. *Megalops atlanticus* (tarpon).  
Mesohaline, oligohaline; open lagoon, marshes, ditches, impoundments; occasional; larger individuals found in open lagoon areas, concentrating around heated power-plant effluent in winter; small individuals occasionally found in brackish ditches, creeks, and impoundments, although apparently not so commonly as further south (Gilmore, 1977a).

FAMILY ALBULIDAE – bonefishes

17. *Albula vulpes* (bonefish).

Mesohaline; open lagoon; rare; 1 recently transformed individual seined in Banana River and 1 juvenile from FP&L site on Indian River; apparently more common further south in lagoon system (Gilmore et al., 1978).

FAMILY ANGUILLIDAE – freshwater eels

18. *Anguilla rostrata* (American eel).

Mesohaline, possibly oligohaline; open lagoon, possibly ditches; abundance unknown but probably occasional; the sampling procedures employed were not ideal for collecting eels.

FAMILY OPHICHTHIDAE – snake eels

19. *Myrophis punctatus* (speckled worm eel).

Mesohaline; open lagoon; abundance unknown but probably frequent; most captures at night, when relatively little sampling was conducted.

20. *Ophichthus gomezi* (shrimp eel).

Mesohaline; open lagoon; probably rare (Snelson, 1981).

FAMILY CLUPEIDAE – herrings

21. *Brevoortia smithi* (yellowfin menhaden).

Mesohaline; open lagoon; common.

22. *Brevoortia tyrannus* (Atlantic menhaden).

Mesohaline; open lagoon; frequent; notably less abundant than *B. smithi*; putative hybrids between the 2 menhaden species not uncommon (Dahlberg, 1970).

23. *Dorosoma cepedianum* (gizzard shad).

Mesohaline, oligohaline, fresh; open lagoon, ditches, impoundments; occasional; collected sporadically in wide variety of habitats; normally considered a freshwater species but found at salinities up to 37 ppt in Texas (Simmons, 1957).

24. *Harengula jaguana* (scaled sardine).

Mesohaline; open lagoon; abundant; prior to mid-1970s, this species was named *Harengula pensacolae* (Whitehead, 1973).

25. *Opisthonema oglinum* (Atlantic thread herring).

Mesohaline; open lagoon; common.

FAMILY ENGRAULIDAE – anchovies

26. *Anchoa cubana* (Cuban anchovy).

Mesohaline; open lagoon; occasional. The relative abundance of the 3 primary anchovy species in the study area is illustrated by trawl collections made in the summers of 1979 and 1980. The total catch of 93,244 anchovies was apportioned as follows: 92,558 (99.26%) *A. mitchilli*, 665 (0.71%) *A. hepsetus*, and 21 (0.02%) *A. cubana*.

27. *Anchoa hepsetus* (striped anchovy).

Mesohaline; open lagoon; frequent; widespread but never taken in large numbers.

28. *Anchoa mitchilli* (bay anchovy).

Mesohaline; open lagoon, lagoon perimeter; abundant; the most abundant marine fish in study area.

29. *Anchoa nasuta* (longnose anchovy).

Mesohaline; open lagoon; rare; a single specimen taken in April 1978 in Mosquito Lagoon.

FAMILY SYNODONTIDAE – lizard fishes

30. *Synodus foetens* (inshore lizardfish).

Mesohaline; open lagoon; occasional.

FAMILY CYPRINIDAE – minnows

31. *Notemigonus crysoleucas* (golden shiner).

Fresh; ponds, impoundments, ditches; frequent; taken only in permanent bodies of water.

FAMILY CATOSTOMIDAE – suckers

32. *Erimyzon sucetta* (lake chubsucker).

Fresh; ponds, impoundments, ditches; frequent; taken only in permanent bodies of water around dense vegetation.

FAMILY ICTALURIDAE – bullhead catfishes

33. *Ictalurus natalis* (yellow bullhead).

Fresh; ponds, impoundments, ditches; abundance unknown but probably occasional; because suitable sampling procedures were not frequently employed, collection records probably underrepresent abundance of this species on Merritt Island.

FAMILY ARIIDAE – sea catfishes

34. *Arius felis* (hardhead catfish).

Mesohaline; open lagoon; common.

35. *Bagre marinus* (gafftopsail catfish).

Mesohaline; open lagoon; frequent.

FAMILY BATRACHOIDIDAE – toadfishes

36. *Opsanus tau* (oyster toadfish).

Mesohaline; open lagoon, lagoon perimeter; frequent.

FAMILY GOBIESOCIDAE – clingfishes

37. *Gobiesox strumosus* (skilletfish).

Mesohaline; open lagoon; abundance unknown but probably frequent; because of its habit of clinging to and hiding under objects, my capture records, primarily with nets, probably underrepresent abundance of this species.

FAMILY OPHIDIIDAE – cusk-eels

38. *Ophidion marginatum* (striped cusk-eel).

Mesohaline; open lagoon; rare (Snelson, 1981).

FAMILY EXOCOETIDAE – flyingfishes

39. *Cypselurus melanurus* (Atlantic flyingfish).

Mesohaline; open lagoon; rare; a single individual found at FP&L plant on Indian River, July 1979; this species was referred to as *Cypselurus heterurus* prior to 1970 (Gibbs and Staiger, 1970).

40. *Hyporhamphus unifasciatus* (halfbeak).

Mesohaline; open lagoon; occasional; encountered infrequently but in large schools.

FAMILY BELONIDAE – needlefishes

41. *Strongylura marina* (Atlantic needlefish).

Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; occasional; not collected in freshwater habitats on Merritt Island (c.f., Herald and Strickland, 1949; McLane, 1955; Tagatz, 1968).

42. *Strongylura notata* (redfin needlefish).

Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common; the most abundant of the 3 needlefish species in study area (Snelson and Bradley, 1978).

43. *Strongylura timucu* (timucu).

Mesohaline; open lagoon, lagoon perimeter; rare; a single specimen collected October 1976 in Banana River near Port Canaveral; Schooley (1980) reported a single specimen from Mosquito Lagoon. Because of the nature of the diagnostic characters (Collette, 1968), it is difficult to distinguish *S. timucu* and *S. marina* specimens less than 30 mm standard length. Nevertheless, careful evaluation of all large specimens available demonstrates that *S. timucu* is quite rare.

FAMILY CYPRINODONTIDAE – killifishes

44. *Cyprinodon variegatus* (sheepshead minnow).  
Oligohaline, mesohaline; impoundments, ditches, marshes, occasionally lagoon perimeter; abundant; characteristic of protected areas with sand-silt sediments; distribution complementary to that of next species.
45. *Floridichthys carpio* (goldspotted killifish).  
Mesohaline, occasionally oligohaline; lagoon perimeter, marshes; abundant; unlike preceding species, this one never found in either impoundments or ditches on Merritt Island; characteristic of exposed, wave-washed shore zones, where bottom sediments sand-shell and vegetation sparse; occasionally trawled in open lagoon in areas with abundant drift algae.
46. *Fundulus chrysotus* (golden topminnow).  
Fresh; ditches, impoundments, ponds; frequent; typical of areas with dense submerged and emergent vegetation; widely distributed on Merritt Island, but nowhere abundant.
47. *Fundulus confluentus* (marsh killifish).  
Oligohaline, occasionally mesohaline; impoundments, ditches, marshes; frequent; although rarely seined, often collected in numbers in baited minnow traps; an inhabitant of freshwater environments on mainland (Relyea, 1975) but never collected in freshwater on Merritt Island.
48. *Fundulus grandis* (gulf killifish).  
Mesohaline, oligohaline; impoundments, ditches, marshes, lagoon perimeter; common.
49. *Fundulus heteroclitus* (mummichog).  
Only record from Indian River region is report by Relyea (1975) from near Edgewater, north of my study area; the locality is in Volusia County, not Brevard County as stated by Relyea.
50. *Fundulus seminolis* (Seminole killifish).  
Fresh, oligohaline; impoundments, ponds, ditches, marshes; occasional; although usually a freshwater species on mainland (Relyea, 1975; DuRant et al., 1979), collected sporadically over wide salinity range (0-25 ppt) in and around Merritt Island.
51. *Fundulus similis* (longnose killifish).  
Mesohaline; lagoon perimeter; occasional.
52. *Jordanella floridae* (flagfish).  
Fresh; ditches, ponds, impoundments; frequent; always found in small numbers; characteristic of areas with dense submerged and emergent vegetation.
53. *Lucania goodii* (bluefin killifish).  
Fresh; ponds, ditches, impoundments; common; the few individuals collected in brackish waters appeared to be wafted from adjacent freshwater areas during periods of high water; characteristic of habitats with abundant submerged and emergent vegetation.
54. *Lucania parva* (rainwater killifish).  
Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common to abundant; habitat and abundance pattern contrasts sharply with preceding species; most abundant in shallow brackish waters where vegetation sparse or nonexistent; in open lagoons, closely associated with beds of drift algae and seagrasses; although common in essentially fresh waters of St. Johns River basin (Tagatz, 1968), collected infrequently and in low abundance in fresh waters on Merritt Island.

FAMILY POECILIIDAE – livebearers

55. *Gambusia affinis* (mosquitofish).  
Fresh, oligohaline, mesohaline; virtually ubiquitous except for the open lagoon waters; abundant.

56. *Heterandria formosa* (least killifish).  
Fresh; ponds, impoundments, ditches; frequent; collected regularly but in low abundance in habitats where submerged aquatic vegetation was dense.
57. *Poecilia latipinna* (sailfin molly).  
Mesohaline, oligohaline, fresh; lagoon perimeter, ditches, impoundments, marshes; abundant; rare in open lagoon areas and encountered regularly but in low numbers in strictly freshwater; everywhere abundant in protected mesohaline and oligohaline waters, especially where submerged vegetation dense.
- FAMILY ATHERINIDAE – silversides**
58. *Membras martinica* (rough silverside).  
Mesohaline; lagoon perimeter; occasional; collected only twice, once around spoil island in northern Indian River and once in Haulover Canal; additional night collecting may prove this species to be more common than my records indicate.
59. *Menidia beryllina* (inland silverside).  
Oligohaline, fresh; ditches, impoundments; occasional.
60. *Menidia peninsulae* (tidewater silverside).  
Mesohaline, oligohaline; lagoon perimeter, marshes, ditches, impoundments; abundant. Silverside populations associated directly with the lagoon system appear to be *M. peninsulae*. Populations from some low salinity ditches and impoundments on Merritt Island are tentatively identified as *M. beryllina*. However, some populations from brackishwater habitats on Merritt Island are not clearly assignable to either species on the basis of diagnostic morphological characters emphasized by Johnson (1975) and Chernoff et al. (1981), suggesting the possibility of hybridization.
- FAMILY SYNGNATHIDAE – pipefishes**
61. *Hippocampus erectus* (lined seahorse).  
Mesohaline; open lagoon, lagoon perimeter; occasional; much less common than following species.
62. *Hippocampus zosterae* (dwarf seahorse).  
Mesohaline; open lagoon, lagoon perimeter; frequent; typically found in shallow seagrass beds.
63. *Syngnathus louisianae* (chain pipefish).  
Mesohaline; open lagoon; occasional; characteristic of deeper areas; usually collected by trawling in areas where little or no vegetative cover was present.
64. *Syngnathus scovelli* (gulf pipefish).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; common to abundant in seagrass beds and drifting macroalgae (Kulczycki et al., 1981; Mulligan and Snelson, 1982); not collected in fresh water on Merritt Island.
- FAMILY CENTROPOMIDAE – snooks**
65. *Centropomus undecimalis* (snook).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; frequent; adults characteristic of deeper water, especially in dredged areas and around bridges, navigation markers, and other protective cover; juveniles usually in oligohaline creeks; suffered considerable stress and mortality during unusually cold winter of 1977 (Snelson and Bradley, 1977; Gilmore et al., 1978).
- FAMILY SERRANIDAE – sea basses**
66. *Cetropristis philadelphica* (rock sea bass).  
Mesohaline; open lagoon; rare; only 2 specimens known from study area, 1 trawled near northern end of Indian River, 1 collected at FP&L site on Indian River.
67. *Mycteroperca microlepis* (gag).  
Mesohaline; open lagoon; occasional; 6 records, all from Mosquito Lagoon.
- FAMILY CENTRARCHIDAE – sunfishes**
68. *Lepomis gulosus* (warmouth).  
Fresh; ditches, ponds, impoundments; frequent; a secretive species typically collected in close association with vegetation, overhanging brush, and other types of protective cover.

69. *Lepomis macrochirus* (bluegill).  
Fresh; ponds, ditches, impoundments; common; typically found in larger, more-permanent bodies of water.
70. *Lepomis marginatus* (dollar sunfish).  
Fresh; ponds, ditches, impoundments; occasional; a small, secretive species inhabiting shallow, weedy, littoral areas; collected at scattered localities throughout Merritt Island.
71. *Lepomis microlophus* (reardear sunfish).  
Fresh; ponds, ditches, impoundments; frequent; co-occurred with *L. macrochirus* throughout Merritt Island but usually less abundant.
72. *Lepomis punctatus* (spotted sunfish).  
Fresh; ditches; rare; collected at a single site on Merritt Island, a roadside ditch 0.5 km E. jct. Hwys. 402 and 3; 10 specimens were taken in 31 collections at this site between November 1972 and May 1975.
73. *Micropterus salmoides* (largemouth bass).  
Fresh, occasionally oligohaline; ditches, ponds, impoundments; frequent; typically found in larger, deeper, more-permanent bodies of water.
74. *Pomoxis nigromaculatus* (black crappie).  
Fresh; impoundments; only 1 individual captured, but fishermen claim there are good populations in 2 freshwater impoundments.
- FAMILY POMATOMIDAE – bluefishes
75. *Pomatomus saltatrix* (bluefish).  
Mesohaline; open lagoon; occasional; records sporadic but from all seasons, indicating this species is a year-round inhabitant.
- FAMILY ECHENEIDAE – remoras
76. *Echeneis naucrates* (sharksucker).  
Mesohaline; open lagoon; rare (Snelson and Bradley, 1978; Snelson, 1981).
77. *Echeneis neucratoides* (whitfin sharksucker).  
Mesohaline; open lagoon; rare (Snelson, 1981).
- FAMILY CARANGIDAE – jacks
78. *Caranx crysos* (blue runner).  
Mesohaline; open lagoon; rare (Snelson and Bradley, 1978).
79. *Caranx hippos* (crevalle jack).  
Mesohaline; open lagoon; common.
80. *Caranx latus* (horse-eye jack).  
Mesohaline; open lagoon; occasional; appears to travel in schools with preceding species, but always much less abundant.
81. *Chloroscombrus chrysurus* (Atlantic bumper).  
Mesohaline; open lagoon; occasional.
82. *Oligoplites saurus* (leatherjacket).  
Mesohaline; open lagoon, lagoon perimeter; frequent; young often float motionless just below surface, mimicking drifting pieces of seagrass or algae.
83. *Selene setapinnis* (Atlantic moonfish).  
Mesohaline; open lagoon; rare; 1 specimen collected by gill net in Mosquito Lagoon and 1 trawled in northern end of Indian River; until recently, this species went under the genus name *Vomer* (Berry and Smith-Vaniz, 1978).
84. *Selene vomer* (lookdown).  
Mesohaline; open lagoon; occasional; in addition to specimen reported by Snelson and Bradley (1978), 2 juveniles trawled in Banana River near Port Canaveral, 2 adults recovered from FP&L station on Indian River, and 2 juveniles trawled in northern part of Mosquito Lagoon.
85. *Trachinotus carolinus* (Florida pompano).  
Mesohaline; open lagoon; occasional; collected sporadically throughout study region; experienced gill-net fishermen occasionally take commercially significant quantities, especially during late summer and fall (Anderson and Gehringer, 1965; Snelson, 1980a).

86. *Trachinotus falcatus* (permit).

Mesohaline; open lagoon; occasional; less abundant than preceding species but occasionally taken in numbers by gill-net fishermen (Snelson and Bradley, 1978; Snelson, 1980a).

FAMILY LUTJANIDAE – snappers

87. *Lutjanus griseus* (gray snapper).

Mesohaline; open lagoon, lagoon perimeter; frequent; usually found around cover such as pilings, bridges, and riprap; occasionally taken in commercial quantities by gill-net fishermen in Mosquito Lagoon (Snelson, 1980a). Schooley (1980) reported a single specimen of another lutjanid species, *Lutjanus synagris*, from Mosquito Lagoon; but the specimen is not available for confirmation.

FAMILY LOBOTIDAE – tripletails

88. *Lobotes surinamensis* (tripletail).

Mesohaline; open lagoon; rare; 5 specimens, all taken in August and September 1979 from intake screens at FP&L power plant on Indian River.

FAMILY CERREIDAE – mojarras

89. *Diapterus auratus* (Irish pompano).

Mesohaline; open lagoon; frequent; young and juveniles encountered more often than adults; usually found over soft sand-silt bottoms; until recently, this species was named *Diapterus olisthostomus* (Miller, 1976).

90. *Diapterus plumieri* (striped mojarra).

Mesohaline; open lagoon; rare; only 2 specimens known from study region, 1 from Banana River (Snelson and Bradley, 1978), 1 from Indian River at Frontenac.

91. *Eucinostomus argenteus* (spotfin mojarra).

Mesohaline; open lagoon, lagoon perimeter; common; this and following species usually collected together, seem to show little habitat segregation; usually found over soft silt or sand-silt bottoms.

92. *Eucinostomus gula* (silver jenny).

Mesohaline; open lagoon, lagoon perimeter; common. Schooley (1977) reported *E. lefroyi* from Banana River but specimens are not available for confirmation.

FAMILY HAEMULIDAE – grunts

93. *Orthopristis chrysoptera* (pigfish).

Mesohaline; open lagoon; frequent; usually associated with seagrass beds; often caught in traps and sold as preferred bait for hook and line fishing for large spotted seatrout (Tabb, 1960; pers. observ.). Schooley (1980) reported another haemulid species, *Haemulon sciurus*, from Mosquito Lagoon; but the specimens are not available for confirmation.

FAMILY SPARIDAE – porgies

94. *Archosargus probatocephalus* (sheepshead).

Mesohaline; open lagoon; common; usually found around structures such as piers, navigation markers, and bridges.

95. *Lagodon rhomboides* (pinfish).

Mesohaline; open lagoon, lagoon perimeter; common to abundant; usually associated with seagrass beds.

FAMILY SCIAENIDAE – drums

96. *Bairdiella chrysoura* (silver perch).

Mesohaline; open lagoon; abundant.

97. *Cynoscion nebulosus* (spotted seatrout).

Mesohaline; open lagoon; common; a highly prized sport and commercial species; by dollar value, the most important commercial fin-fish in lagoon system (Anderson and Gehringer, 1965); Indian River system populations grow faster than any other Florida population examined by Tabb (1961).

98. *Cynoscion regalis* (weakfish).

Mesohaline; open lagoon; frequent; only young and juveniles taken, most by trawling.

99. *Leiostomus xanthurus* (spot).  
Mesohaline; open lagoon; common to abundant; usually trawled over unvegetated sand or sand-silt bottoms; a significant commercial species in lagoon system (Anderson and Gehringer, 1965; Snelson, 1980a).
100. *Menticirrhus americanus* (southern kingfish).  
Mesohaline; open lagoon; frequent; adults most common in winter and early spring months. Schooley (1977) reported a single individual of *M. saxatilis* from the Indian River near Titusville, but the specimen is not available for confirmation.
101. *Micropogonias undulatus* (Atlantic croaker).  
Mesohaline; open lagoon; frequent; a valuable food fish but not taken in significant commercial quantities in study area (Snelson, 1980a); until recently, treated under generic name *Micropogon* (Chao, 1978).
102. *Pogonias cromis* (black drum).  
Mesohaline; open lagoon, lagoon perimeter, marshes; frequent; large adults up to 28 kg taken in gill nets in open lagoon; young usually taken in mangrove-lined shore zones.
103. *Sciaenops ocellata* (red drum).  
Mesohaline; open lagoon, lagoon perimeter, marshes; frequent to common; young and juveniles usually taken in shallow shore zones; large adults up to 16 kg taken in gill nets in deeper water; an important sport and food fish.
- FAMILY EPHIPPIDAE – spadefishes**
104. *Chaetodipterus faber* (Atlantic spadefish).  
Mesohaline; open lagoon; frequent to common around docks, bridges, and navigation markers.
- FAMILY SCARIDAE – parrotfishes**
105. *Nicholsina usta* (emerald parrotfish).  
Mesohaline; open lagoon; rare; only 3 individuals taken, all impinged on water intake screens at FP&L power plant, summer 1979.
- FAMILY MUGILIDAE – mullets**
106. *Mugil cephalus* (striped mullet).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common to abundant; based on annual landings, the most important commercial fish species in lagoon system, with greatest landings between July and October (Anderson and Gehringer, 1965; Snelson, 1980a).
107. *Mugil curema* (white mullet).  
Mesohaline; open lagoon, lagoon perimeter, marshes; common to abundant; unlike situation further south in lagoon system (Gilmore, 1977a), not found in impounded brackish waters on Merritt Island; smaller than preceding species, of limited commercial value.
- FAMILY SPHYRAENIDAE – barracudas**
108. *Sphyraena barracuda* (great barracuda).  
Mesohaline; open lagoon; rare; 1 young seined near Port Canaveral locks in Banana River, 1 juvenile caught by sport fisherman in Banana River.
109. *Sphyraena borealis* (northern sennet).  
Mesohaline; open lagoon; rare; single specimen from FP&L power plant on Indian River.
- FAMILY URANOSCOPIDAE – stargazers**
110. *Astroscopus y-graecum* (southern stargazer).  
Mesohaline; open lagoon; rare; 1 specimen from Mosquito Lagoon, 1 from Indian River.
- FAMILY BLENNIIDAE – combtooth blennies**
111. *Chasmodes saburrae* (Florida blenny).  
Mesohaline; open lagoon, lagoon perimeter; common; typically taken in seagrass beds, shell beds, riprap, and other types of protective cover.
112. *Hypleurochilus geminatus* (crested blenny).  
Mesohaline; open lagoon; rare (Snelson, 1981).

FAMILY ELEOTRIDAE – sleepers

113. *Dormitator maculatus* (fat sleeper).  
Oligohaline, fresh; marshes, ditches; occasional; usually found in small ditches or canals draining directly into lagoon.

FAMILY GOBIIDAE – gobies

114. *Bathygobius soporator* (frillfin goby).  
Mesohaline; lagoon perimeter; rare; a single specimen collected in northern end of Banana River; there is very little suitable habitat for this species in study area.
115. *Evarthodus lyricus* (lyre goby).  
Mesohaline; lagoon perimeter, marshes; rare; small sample taken on 2 separate occasions at same site near Port Canaveral locks in Banana River; not found in other areas where habitat seemed to be suitable.
116. *Gobioides broussoneti* (violet goby).  
Mesohaline; open lagoon; rare; 2 specimens taken at FP&L site on Indian River.
117. *Gobionellus holeosoma* (darter goby).  
Mesohaline; open lagoon, lagoon perimeter; occasional; collected irregularly in small numbers in Banana River and Indian River; much more common north (Ponce de Leon Inlet) and south (Sebastian Inlet) of study area.
118. *Gobionellus oceanicus* (highfin goby).  
Mesohaline; open lagoon; occasional; found throughout study area but always uncommon; some evidence suggests that it is most active at night. Both *G. oceanicus* and *G. hastatus* have been reported from the lagoon system (Gilmore, 1977a; Snelson, 1980a), but recent studies by Mr. Frank Pezold (pers. comm.) indicate that only one variable species is present.
119. *Gobionellus smaragdus* (emerald goby).  
Mesohaline; open lagoon; rare; 2 individuals taken in Banana River near the Port Canaveral locks.
120. *Gobiosoma hoset* (naked goby).  
Oligohaline; marshes, ditches, impoundments; frequent; characteristic of low-salinity habitats.
121. *Gobiosoma robustum* (code goby).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; abundant; strongly associated with the drift macroalgae community (Kulczycki et al., 1981; Mulligan and Snelson, 1982), but found in a diversity of habitats; characteristically inhabits higher salinities than preceding species, although they were taken together at one brackish ditch on several occasions.
122. *Microgobius gulosus* (clown goby).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common; usually collected over soft sand or silt substrates; not collected in strictly fresh water on Merritt Island.
123. *Microgobius thalassinus* (green goby).  
Mesohaline; open lagoon; occasional; collected most often in trawl over bare sand-silt bottoms; found irregularly throughout study area but always in small numbers.

FAMILY TRICHIURIDAE – cutlassfishes

124. *Trichiurus lepturus* (Atlantic cutlassfish).  
Mesohaline; open lagoon; occasional; seasonally common in Port Canaveral and around inlets, but sporadic in northern part of lagoon system.

FAMILY SCOMBRIDAE – mackerels

125. *Scomberomorus maculatus* (Spanish mackerel).  
Mesohaline; open lagoon; occasional; a few specimens from Mosquito Lagoon and Banana River (Snelson and Bradley, 1978); infrequently caught by commercial fishermen in Banana River.

- FAMILY SCORPAENIDAE – scorpionfishes
126. *Scorpaena brasiliensis* (barbfish).  
Mesohaline; open lagoon; rare; 4 specimens, all taken at FP&L power plant on Indian River.
- FAMILY TRIGLIDAE – searobins
127. *Prionotus scitulus* (leopard searobin).  
Mesohaline; open lagoon; occasional; records from Mosquito Lagoon and Indian River.
128. *Prionotus tribulus* (bighead searobin).  
Mesohaline; open lagoon; frequent.
- FAMILY BOTIIDAE – lefteye flounders
129. *Citharichthys spilopterus* (bay whiff).  
Mesohaline; open lagoon; occasional; scattered records from Mosquito Lagoon and Indian River.
130. *Etropus crossotus* (fringed flounder).  
Mesohaline; open lagoon; rare; a single specimen taken June 1979 at FP&L power plant on Indian River.
131. *Paralichthys albigutta* (gulf flounder).  
Mesohaline; open lagoon; frequent.
132. *Paralichthys lethostigma* (southern flounder).  
Mesohaline; open lagoon; occasional; encountered only about half as often as preceding species.
- FAMILY SOLEIDAE – soles
133. *Achirus lineatus* (lined sole).  
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches; common.
134. *Trinectes maculatus* (hogchoker).  
Oligohaline; lagoon perimeter, marshes, ditches, impoundments; frequent; occurs at lower salinities than preceding species but not collected in fresh water on Merritt Island.
- FAMILY CYNOGLOSSIDAE – tonguefishes
135. *Symphurus plagiusa* (blackcheek tonguefish).  
Mesohaline; open lagoon; occasional.
- FAMILY BALISTIDAE – leatherjackets
136. *Aluterus schoepfi* (orange filefish).  
Mesohaline; open lagoon; rare; 2 specimens from Indian River, 1 near Titusville, 1 at Frontenac.
137. *Monacanthus hispidus* (planehead filefish).  
Mesohaline; open lagoon; common around bridges, piers, navigation markers, and similar structures.
- FAMILY TETRAODONTIDAE – puffers
138. *Sphoeroides nephelus* (southern puffer).  
Mesohaline; open lagoon, lagoon perimeter; common; strongly associated with seagrass beds.
139. *Sphoeroides spengleri* (bandtail puffer).  
Mesohaline; open lagoon, lagoon perimeter; occasional; 1 specimen from Banana River (Snelson and Bradley, 1978) and several from Indian River between Frontenac and Titusville.
140. *Sphoeroides testudineus* (checkered puffer).  
Mesohaline; open lagoon; rare; 1 specimen from FP&L site on Indian River.
- FAMILY DIODONTIDAE – porcupinefishes
141. *Chilomycterus schoepfi* (striped burrfish).  
Mesohaline; open lagoon, lagoon perimeter; common; the related *Diodon hystrix* was reported from Cocoa by Evermann and Bean (1897) but has not been collected anywhere in lagoon system in recent years (Gilmore, 1977a).





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13. ABSTRACT (Maximum 200 words) This document provides a synopsis of biotic and abiotic data collected in the Mosquito Lagoon area in relation to water quality. A holistic ecological approach was used in this review to allow for summaries of climate, land use, vegetation, geohydrology, water quality, fishes, sea turtles, wading birds, marine mammals, invertebrates, shellfish and mosquito control. The document includes a bibliographic database list of 157 citations that have references to the Mosquito Lagoon, many of which were utilized in development of the text.				
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